PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

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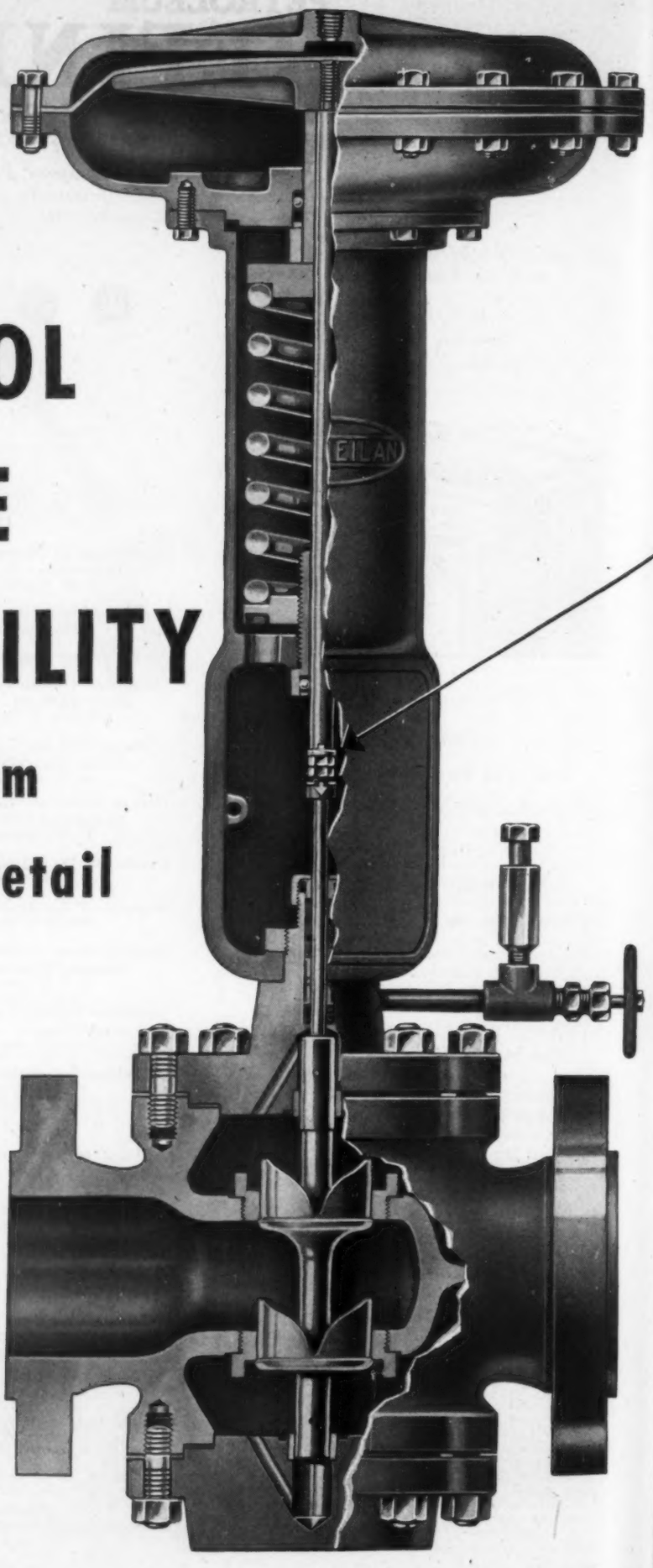
Results from Attention to Detail



NOTE: One skirt of the valve plug is shown 90° out of position in relation to the other skirt.

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THE LOOK BOX

BY ONLY one measure, technical accomplishment, does it seem reasonable that the Natural Gasoline Association of America has earned the right to its Silver Jubilee. Otherwise it does not seem that it was more than a quarter century ago that a few men set about to arrive at some specifications for a product of low industry standing. Since then its contributions to technology have outstripped expectations. Unfortunately the contributions outweigh the money reward.

Quarter Century

Along with improving the technique of separating the lighter hydrocarbons for its own benefit, this division of the industry has provided the knowledge for similar improvements in refining. In benefiting itself it has benefited others, a typical consequence in any advancement.

Briefly stated, the natural gasoline part of this industry has learned how to deliver pure hydrocarbons into commercial channels.

Now the time has come for a chance in the use of these products. In the past quarter century the products of natural gasoline recovery and separation have gone chiefly into motor fuel. In the next quarter century a part of fruits of natural gasoline manufacture will go into petro-chemical processing. Only a few of these plants are operating; more are planned; the extent of this processing defies calculation.

The whole prospect raises a question—will the natural gasoline segment of this industry profit from petro-chemical processing by more than it has from refining? It has had but one customer over the past quarter century—the refining plant. In the next quarter century it will have its old customer plus a young and growing one.

The admonition seems clear. Natural gasoline should engage in petro-chemical processing. It has the choice raw materials. It has personnel capable of wise guidance. These are not the only requirements for petro-chemical processing. They are sufficient to justify thorough consideration. Out of such a background, it is to be expected that the next quarter century will bring technical contributions more significant than those of the past period. It is hoped that the monetary rewards will outstrip the past quarter century.

ON THE simple basis of providing supply equal to or in excess of demand the petroleum industry deserves to be released from OPA price restrictions. That this release will not come about because of this accomplishment is well understood. But the reasons for further investigation by OPA bring the investigator into the network of Washington, where the common assumption is that both wisdom and virtue have been concentrated in beneficent supply.

Slightly Involved

For instance here is a part of the communication from J. H. Reppert, associate director, fuel division, OPA, for delivery before the meeting of Western Petroleum Refiners Association last month in Fort Worth:

"I believe the most important part of my job now is to effect a successful price suspension program for your industry which will be consistent with the stabilization program, in that prices will not generally rise above *legal limits* after suspension takes place."

He then admits of the difficulty of explaining "legal limits," which seem to be a pair of new

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words in OPA ramifications. It seems that the refining industry must provide a wealth of information through the return of questionnaires from which:

"If . . . your current or prospective earnings will fall below the amount you earned during 1936 through 1939 then it is OPA's responsibility to establish relatively higher prices that will return earnings comparable to this peacetime base period. Now if the industry situation is what we assume it to be, and what you refiners say it is, then presumably you will be entitled to a price increase which would become the legal limit at which we would suspend price control."

It would seem that a lot of mental toe dancing is in prospect before anyone can decide what to do about suspension.

What the refining industry should do is turn its guns on the members of Congress. There is ample crude oil and the refining industry is capable of making all of the finished products the American people need. That and that alone is sufficient reason for moving cancellation of OPA regulations.

The more questions, the more answers, the more answers, the more study, the more study, the more confusion, out of which come such guiding words as "legal limits," which seem to confuse the man who wrote them.

Hope or Warning

IN HIS remarks before the annual meeting of the Western Petroleum Refiners Association, E. O. Thompson analyzed the advantages of processing higher gravity charge stocks to the conclusion that 40 percent additional profit can be had by processing raw material of 60° API as compared with 40°. "This," to quote, "holds true only if the process design is proper for the purpose."

It is reasonable to expect such a difference in profit between two such raw materials but it is not reasonable to expect the refining industry, especially the ownership of its smaller plants, to take early advantage of this profit possibility. It was proper that larger refining units had the advantage of newer processes in order to assure war products.

These processes are adaptable to smaller plants but the situation in materials and labor is such that immediate modernization of the whole industry is beyond hope. If steel were at hand and men ready to erect it, the building of refining plants involves a time lag that deserves respect. For that reason the element of warning from the member of the Texas Railroad Commission is difficult to understand.

Part of his conclusion was, "the purpose of my paper will be served if the refiners are informed that a billion cubic feet of natural gas now being flared daily in Texas is forthwith to be required to be utilized . . . The Railroad Commission of Texas is determined to do its full duty in stopping flares of casinghead gas. These gases will furnish more and more your raw material."

Flare gas is largely methane and no refining plant in the United States is equipped to use it as raw material. Only one such plant is under consideration and its completion is at least a year hence. The refining industry is not equipped to use methane and will not be for several years. Processes have to be proved before plants are generally considered.

Ten Years From Now

THROUGH plant expansion and technological developments the manufacturing division of the industry will take care of an expanding motor fuel demand over the next 10 years without using additional crude oil supplies in the opinion of H. W. Page, Standard Oil Company (New Jersey), whose views were explained before the annual meeting of the AIMME meeting in Chicago.

In his opinion sufficient cycling and natural gasoline plants will be provided to increase the daily total of this output from its present 300,000 barrels to 400,000 barrels. Also the synthesis of natural gas will in that time provide 200,000 barrels of motor fuel daily. (The first plant of this nature has been announced.) Meanwhile refinery modernization will allow more motor fuel to be made from crude oil.

This program of cutting deeper into crude oil for light products will in the opinion of this economist avoid the necessity of making too much fuel oil, which is of low value since it must at all times compete with coal.

Such increases as may be required in fuel oil can be provided through imports of residuals from South America or the import of crude oil from that area.

Diesel Power

DIESEL power now provides 10 percent of the railway requirement in the United States, according to R. Tom Sawyer, American Locomotive Company, before the recent meeting of ASME in Washington. The figure includes switch engines. As for the future he added:

"In the next 10 years this percentage should increase to at least 20 percent or even 40 percent.

"Each type of power will find its own place. No one is going to push one type more than another unless it pays to do so, and the railroads will put that type of locomotive in service which gives the greatest return on investment."

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Calculation of Minimum Reflux Ratio For Multicomponent Distillation

F. D. MAYFIELD and J. A. MAY
The Dow Chemical Company, Freeport, Texas

A METHOD is presented for calculation of minimum reflux ratio for multicomponent distillation. In application the method is quite rapid, but is limited at the present development to complete separations of mixtures which involve only one component in the distillate or only one component in the bottom product. Further study should permit extension of this method to include all types of separations.

IN PROCESS engineering design of continuous distillation columns it is desirable to know the plates required at different reflux ratios, the proper feed plate location, and the temperature (or concentration) gradient through the column, the latter being of importance for automatic control of the column. Some methods for predicting plates and reflux give all this information, while others do not give feed-plate location nor temperature (concentration) gradient. The calculation methods for two component separations are rapid and easy to apply, but the multicomponent methods are relatively slow and tedious.

The purpose of this study is to present a new approach to the multicomponent problem which, for many multicomponent separations, will offer a speedy and simple solution for minimum reflux.

Before developing the theory of this method it is thought desirable to point out features of some of the calculation methods, together with some pertinent characteristics encountered in two-component and in multicomponent separations.

Two-Component Separations

In the process design of continuous distillation columns the plates and reflux required for two-component separations can be determined by means of the graphical, plate-to-plate method of McCabe & Thiele[8]; this method is quite simple, thoroughly dependable,* and has the added advantage of indicating the feed-plate location and the temperature gradient through the column. Another method of greater speed is that of calculation of the minimum reflux by the Underwood[9] or Fenske[4] equations, calculation of the minimum plates by the Underwood[9] or Fenske[4] equations, and calculations of the finite plates at the operating reflux by means of the Brown and Martin[2] chart; this method has the disadvantage of not indicating the feed plate location nor the temperature gradient. It should be noted, however, that Underwood[9] gives an approximate equation for estimating the feed-plate location; also Kirkbride[6] gives an emperical equation for the same determination but fails to report any data to indicate its reliability.

Minimum Reflux Characteristics—Underwood's[9] minimum reflux equation for a feed condition of bubble point liquid is†

$$\left(\frac{L}{D}\right)_m = \frac{1}{\alpha-1}\left[\frac{X_D}{X_F} - \frac{\alpha(1-X_D)}{(1-X_F)}\right] \qquad (1)$$

Expressing the reflux ratio as reflux to feed (L/F)m instead of reflux to distillate (L/D)m, equation (1) becomes

$$\left(\frac{L}{F}\right)_m = \frac{X_F}{(\alpha-1)}\left[\frac{X_D}{X_F} - \frac{\alpha(1-X_D)}{(1-X_F)}\right] \qquad (2)$$

$$= \frac{1}{(\alpha-1)}\left[X_D - \frac{\alpha X_F(1-X_D)}{(1-X_F)}\right] \qquad (3)$$

For complete separations, $X_D = 1.0$ and $X_W = 0.0$ and equation (3) reduces to

$$(L/F)_m = \frac{1}{\alpha-1} \qquad (4)$$

Obviously, then, the minimum reflux-to-feed ratio for complete separations of two-component systems is independent of feed composition, and is a function of relative volatility only (see Table 1 and Figure 1); this is approximately true for incomplete separations, deviating appreciably only for relatively poor separations or for relatively high or low values of X_F (see Table 1 and Figure 1). For this reason it is much safer to keep in mind reflux to feed ratio (L/F) instead of reflux to distillate (L/D).

Another interesting feature is the relationship of minimum reflux for liquid feed to that for vapor feed. For vapor feed

$$(L/D)_m = \frac{1}{\alpha-1}\left[\frac{\alpha X_D}{X_F} - \frac{(1-X_D)}{(1-X_F)}\right] - 1 \qquad (5)$$

For complete separations this becomes

$$(L/D)_m = \frac{\alpha}{(\alpha-1)X_F} - 1 \qquad (6)$$

$D = F X_F$ and $W = F(1-X_F)$

$$\left(\frac{L}{F}\right)_m = \frac{\alpha}{\alpha-1} - X_F \qquad (7)$$

$$\left(\frac{L}{F}\right)_m = \left(\frac{\alpha}{\alpha-1} - 1\right) + (1-X_F) \qquad (8)$$

$$\left(\frac{L}{F}\right)_m = \frac{1}{\alpha-1} + \frac{W}{F} \text{ for dew point vapor feed} \qquad (9)$$

Equation (4) is

$$\left(\frac{L}{F}\right)_m = \frac{1}{\alpha-1} \text{ for bubble point liquid feed} \qquad (4)$$

Equations (4) and (9) give the very simple and

† Nomenclature at end of article.
* When equal molar overflow persists through the column.

TABLE 1

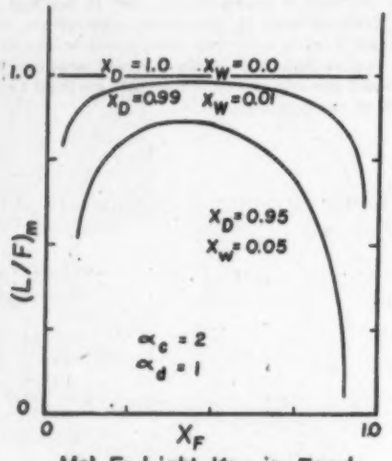
Two Component Separations

Constancy of Minimum Reflux to Feed Ratio

Feed = Bubble Point Liquid

$\alpha_c = 2.0$
$\alpha_d = 1.0$

X_F	$X_D = 1.0$ $X_W = 0.0$		$X_D = .99$ $W_W = .01$		$X_D = .95$ $X_W = .05$	
	(L/D)m	(L/F)m	(L/D)m	(L/F)m	(L/D)m	(L/F)m
0.01	100.0	1.0	.....	.....	.....	.....
0.05	20.0	1.0	19.78	0.81	.....	.....
0.10	10.0	1.0	9.88	0.91	9.39	0.52
0.30	3.33	1.0	3.27	0.97	3.02	0.84
0.50	2.00	1.0	1.94	0.97	1.70	0.85
0.70	1.43	1.0	1.35	0.95	1.02	0.74
0.90	1.11	1.0	0.90	0.82	0.06	0.06
0.95	1.05	1.0	0.64	0.61	.....	.....
0.99	1.01	1.0	.....	.....	.....	.....



Mol Fr. Light Key in Feed

(Two Component Mixture)

FIGURE 1

very useful generalization (applying to complete separations of two component systems) that, for a given *quantity* of feed, the minimum reflux *quantity* for vapor feed equals the minimum reflux *quantity* for liquid feed plus the bottoms *quantity*. This simply means that for vapor feed and liquid bottom withdrawal, additional reflux (over that required for liquid feed) must be returned to the column in sufficient quantity to condense the bottom product portion of the feed. In Table 2 this rule can be seen to hold exactly for complete separations and to hold approximately for incomplete separations, deviating appreciably in the latter case only for relatively high or low feed compositions.

Minimum Plates—Underwood's[9] equation for minimum plates for two component separations is

$$\alpha^{(n+1)} = \frac{(X_D)\,(1 - X_W)}{(1 - X_D)\,(X_W)} \qquad (10)$$

Obviously the value for minimum plates is independent of feed composition, and a finite value for minimum plates is obtained only for incomplete separations.

Multicomponent Separations

Multicomponent separations present a much more difficult problem. If the two-component equations are applied to multicomponent mixtures by treating all the lighter than key components as light key and all the heavier than key components as heavy key, the minimum reflux and minimum plates values obtained will always be high; if the two component equations are applied to multicomponent mixtures by using the actual concentrations of key components, as recommended by Underwood,[9] the results for minimum plates will be correct, while the results for minimum reflux will be sometimes low and sometimes high

Of the reliable methods the only completely informative method is the tedious and time-consuming plate-to-plate method outlined by Lewis and Matheson,[7] which has the advantage of indicating the feed-plate location and temperature gradient through the column as well as the plates and reflux required; it also takes into account changes in molar overflow from plate to plate when encountered. Hummel[5] gives a modification of this method which is useful for speeding up its solution, but it still remains time-consuming.

Another widely used calculation consists of using Colburn's[3] method for minimum reflux, Underwood's[9] or Fenske's[4] equation for minimum plates,* and the Brown and Martin[2] chart for finite plates at operating reflux. This is less time-consuming than the plate-to-plate method, but does not indicate feed-plate location nor temperature gradient through the column.

Minimum Reflux Characteristics—The greater complexity of minimum reflux calculations for multicomponent separations is apparent from a comparison of the minimum reflux—feed composition relationships shown in Figure 2 (which is for complete separation of one type of three-component system) with those shown in Figure 1 (which is for complete separation of a two-component system). Note in

* Applied by using actual concentrations of key components; Brown and Holcomb[1] give an elaboration which is useful when α varies appreciably through the column.

TABLE 2

Two Component Separations

Comparison of Minimum Reflux values for Bubble Point Liquid Feed and for Dew Point Vapor Feed

X_F	F = 1.0 Mole $X_D = 1.0$ $X_W = 0.0$				F = 1.0 Mole $X_D = 0.99$ $X_W = 0.01$				F = 1.0 Mole $X_D = 0.95$ $X_W = 0.05$			
		Liquid Feed		Vap. Feed		Liquid Feed		Vap. Feed		Liquid Feed		Vap. Feed
	W Moles	(L)m Moles	(L)m+W Moles	(L)m Moles	W Moles	(L)m Moles	(L)m+W Moles	(L)m Moles	W Moles	(L)m Moles	(L)m+W Moles	(L)m Moles
0.01	0.99	1.0	1.99	1.99	.....	.....	.....	.....	.....	.....	.....	.....
0.05	0.95	1.0	1.95	1.95	0.96	0.81	1.77	1.93	.....	.....	.....	.....
0.10	0.90	1.0	1.90	1.90	0.91	0.91	1.82	1.88	0.94	0.52	1.46	1.79
0.30	0.70	1.0	1.70	1.70	0.70	0.97	1.67	1.68	0.72	0.84	1.56	1.58
0.50	0.50	1.0	1.50	1.50	0.50	0.97	1.47	1.47	0.50	0.85	1.35	1.35
0.70	0.30	1.0	1.30	1.30	0.30	0.95	1.25	1.26	0.28	0.74	1.02	1.08
0.90	0.10	1.0	1.10	1.10	0.09	0.82	0.91	0.99	0.06	0.06	0.12	0.55
0.95	0.05	1.0	1.05	1.05	0.04	0.61	0.65	0.84	.....	.....	.....	.....
0.99	0.01	1.0	1.01	1.01	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 3

Three Component Separations

Constancy of Minimum Reflux to Feed Ratio

Feed = Bubble Point Liquid
All Cases Are Complete Separations

$\alpha_c = 2.0$
$\alpha_d = 1.0$
$\alpha_e = 0.5$

FEED COMPOSITION MOLE FRACTION			MINIMUM REFLUX RATIOS	
e	c	d	(L/D)m	(L/F)m
0.2	0.01	0.79	86.85	0.8685
0.2	0.40	0.40	2.103	0.8420
0.2	0.75	0.05	1.075	0.8065
0.2	0.79	0.01	1.014	0.8015
0.2	0.80	0.00	0.4168	0.3333
0.4	0.01	0.59	73.22	0.7322
0.4	0.10	0.50	7.205	0.7205
0.4	0.30	0.30	2.293	0.6882
0.4	0.50	0.10	1.2775	0.6388
0.4	0.59	0.01	1.025	0.6050
0.4	0.60	0.00	0.556	0.3333
0.6	0.01	0.39	59.73	0.5973
0.6	0.20	0.20	2.72	0.5440
0.6	0.39	0.01	1.081	0.4220
0.6	0.40	0.00	0.834	0.3333

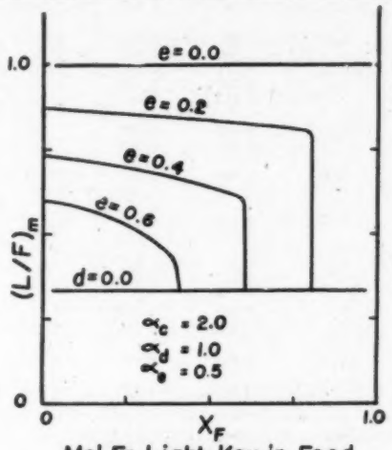


FIGURE 2

Figure 2 and Table 3 that for a fixed mole fraction of heavier than key component in the feed, there is a general trend for minimum reflux to feed (L/F)m to be constant, whereas the minimum reflux to distillate (L/D)m values differ many fold.

Examination of Table 4 shows the general relationship between minimum reflux quantity for liquid feed, minimum reflux quantity for vapor feed, and bottoms quantity which was pointed out previously for two-component separations.

Method of This Paper for Minimum Reflux

This paper presents a rapid and accurate method for calculation of minimum reflux for complete separations of multicomponent mixtures of the (--- a,b, c/d) type and of the (c/d,e,f -----) type where

c and d are the light and heavy keys respectively,
---- a, b are components lighter than the light key,
e, f, ----- are components heavier than the heavy key.

No attempt is made here to apply this method to incomplete separations nor to separations of mixtures of the (--- b,c/d,e ---) type. The concept presented here, however, would seem to have possibilities for further development to include all types of separations.

From consideration of thermodynamic principles, it is postulated that if two or more binary systems (at least of the types considered here), for which the same value of (L/D)m is required, are mixed the minimum reflux ratio required to effect the same separation from the multicomponent mixture is equal to that required for the individual separations as binaries. From this it follows that a multicomponent mixture can be resolved into binaries all of which require an (L/D) minimum equal each to each and to the (L/D) minimum required for the multicomponent separation. A proof of this theory has not been worked out at present but it appears to be confirmed by the comparison of results of a great many calculations carried out stepwise and by the method here presented (see Table 5).

The method of this paper, as indicated above, is to resolve the multicomponent mixture of (n) components into (n — 1) binary separations (see Figure 3) in such a way that the minimum reflux ratios for all of the binaries are numerically equal and also are numerically equal to the minimum reflux ratio for the multicomponent separation; in addition, the

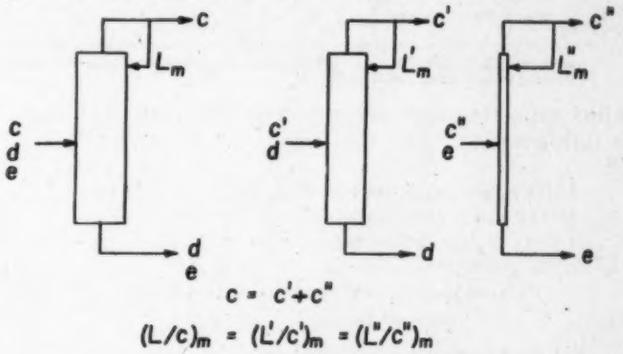


FIGURE 3

material balances for all of the various binary separations combined must be the same as the material balance for the multicomponent separation.

In the developments here presented it is assumed that constant molar overflow exists and that Raoult's law applies.

(c/d,e,f ----) Mixture, Feed = Bubble Point Liquid— Consider the complete separation of an ideal multicomponent system of the (c/d,e,f ----) type with bubble point liquid feed.

Resolve the (c/d,e,f ---) mixture of (n) components into (n — 1) binary mixtures as follows:

Part of c (say c′) with all of d
Part of c (say c″) with all of e
Part of c (say c‴) with all of f and so on, such that
$(c' + c'' + c''' + \text{---} = c)$

For each of the above binaries there is a minimum

TABLE 4

Three Component Separations

Comparison of Minimum Reflux Values for Bubble Point Liquid Feed and for Dew Point Vapor Feed

All Cases Are Complete Separations
Feed = F = 1.0 Mole

X_F				α					Liquid Feed		Vapor Feed
b	c	d	e	b	c	d	e	W Moles	(L)m Moles	(L)m+W Moles	(L)m Moles
..	.3	.3	.4	..	2	1	.5	0.70	0.69	1.37	1.35
..	.3	.3	.4	..	5	1	.5	0.70	0.18	0.88	0.87
..	.2	.2	.6	..	5	1	.5	0.80	0.13	0.93	0.95
.4	.3	.3	..	4	2	1	..	0.30	0.65	0.95	0.99

TABLE 5

Comparison of Minimum Reflux Values Calculated by Colburn Method*, Stepwise Method*, and Method of this Work

MOLE FR. IN FEED						α									
a	b	c	d	e	f	a	b	c	d	e	f	Feed State	Colburn*	(L/D)m* Stepwise	This Work	Percent Dev.†
....	....	0.3	0.3	0.4	....	....	....	2	1	0.5	....	$V=\overline{V}$	2.305	2.295	2.293	−0.1
						....	....	2	1	0.2	....		2.082	2.080	2.080	0.0
						....	....	3	1	0.5	....		1.20	1.18	1.186	+0.5
						....	....	3	1	0.2	....		1.052	1.05	1.053	+0.3
						....	....	1.5	1	0.5	....		4.44	4.425	4.410	−0.3
						....	....	1.5	1	0.2	....		4.11	4.11	4.11	0.0
						....	....	5	1	0.5	....		0.613	0.605	0.607	+0.3
						....	....	5	1	0.2	....		0.531	0.535	0.532	−0.6
....	....	0.2	0.2	0.6	....	....	....	2	1	0.5	....	$V=\overline{V}$	2.69	2.72	2.72	0.0
						....	....	2	1	0.2	....		2.18	2.19	2.19	0.0
						....	....	5	1	0.5	....		0.74	0.765	0.7635	−0.2
....	....	0.4	0.4	0.2	....	....	....	2	1	0.5	....	$V=\overline{V}$	2.11	2.10	2.103	+0.1
						....	....	2	1	0.2	....		2.032	2.030	2.030	0.0
....	....	0.1	0.5	0.4	....	....	....	2	1	0.5	....	$V=\overline{V}$	7.28	7.25	7.205	−0.6
						....	....	2	1	0.2	....		6.40	6.40	6.380	−0.3
....	....	0.5	0.1	0.4	....	....	....	2	1	0.5	....	$V=\overline{V}$	1.274	1.28	1.2775	−0.2
						....	....	2	1	0.2	....		1.215	1.22	1.217	−0.2
....	....	0.25	0.25	0.25	0.25	....	....	2	1	0.5	0.25	$V=\overline{V}$	2.3	2.3	2.3	0.0
....	....	0.3	0.3	0.4	....	....	....	2	1	0.5	....	$V=\overline{V}+F$	4.495	4.483	4.490	+0.2
						....	....	5	1	0.5	....		2.93	2.915	2.907	−0.3
....	....	0.2	0.2	0.6	....	....	....	5	1	0.5	....	$V=\overline{V}+F$	4.74	4.74	4.731	−0.2
....	0.4	0.3	0.3	....	....	....	4	2	1	....	....	$V=\overline{V}$	0.927	0.925	0.924	−0.1
						....	8	2	1	....	....		0.800	0.802	0.800	−0.2
						....	8	4	1	....	....		0.324	0.324	0.3242	+0.1
						....	3	1.5	1	....	....		1.790	1.775	1.785	+0.6
						....	5	1.5	1	....	....		1.642	1.64	1.644	+0.2
....	0.6	0.2	0.2	....	....	....	4	2	1	....	....	$V=\overline{V}$	0.646	0.642	0.644	+0.3
						....	8	2	1	....	....		0.479	0.481	0.480	−0.2
....	0.2	0.4	0.4	....	....	....	4	2	1	....	....	$V=\overline{V}$	1.353	1.350	1.350	0.0
						....	8	2	1	....	....		1.280	1.280	1.280	0.0
....	0.4	0.5	0.1	....	....	....	4	2	1	....	....	$V=\overline{V}$	0.794	0.788	0.7886	+0.1
						....	8	2	1	....	....		0.703	0.702	0.700	−0.3
....	0.4	0.1	0.5	....	....	....	4	2	1	....	....	$V=\overline{V}$	1.01	1.053	1.054	+0.1
						....	8	2	1	....	....		0.84	0.86	0.856	−0.5
....	0.2	0.3	0.4	....	....	....	4	2	1	....	....	$V=\overline{V}$	1.18‡	1.145§	1.182	....
						....	4	1.5	1	....	....		2.254	2.254	2.253	0.0
0.25	0.25	0.25	0.25	....	....	8	4	2	1	....	....	$V=\overline{V}$	0.698	0.698	0.698	0.0
....	0.4	0.3	0.3	....	....	....	4	2	1	....	....	$V=\overline{V}+F$	1.402	1.405	1.411	+0.4

* As reported by Colburn [3]. † Percent deviation of this work value from stepwise value. ‡ Recalculated: was reported by Colburn as 1.143
§ Believed to be in error; should be 1.18.

reflux ratio required to completely separate the binary as follows:

$(L'/D')_m$ for (c', d) binary $= (L'/c')_m$
$(L''/D'')_m$ for (c'', e) binary $= (L''/c'')_m$
$(L'''/D''')_m$ for (c''', f) binary $= (L'''/c''')_m$ and so on.

(Note that for complete separation $D' = c'$, $D'' = c''$, $D''' = c'''$ and so on.)

For the binaries as specified above

$$\left(\frac{L}{D}\right)_m = \left(\frac{L'}{D'}\right)_m = \left(\frac{L''}{D''}\right)_m = \left(\frac{L'''}{D'''}\right)_m = \text{----} \quad (11)$$

For any two component separation for which the feed is liquid at the bubble point

$$\left(\frac{L}{D}\right)_m = \frac{1}{\alpha - 1}\left[\frac{X_D}{X_F} - \frac{\alpha(1-X_D)}{(1-X_F)}\right] \quad (1)$$

For complete separations, $X_D = 1.0$ and

$$\left(\frac{L}{D}\right)_m = \frac{1}{(\alpha-1)X_F} \quad (12)$$

Therefore

$$(\alpha'-1)X'_F = (\alpha''-1)X''_F = (\alpha'''-1)X'''_F \text{----}$$

Then

$$X''_F = \frac{(\alpha'-1)X'_F}{(\alpha''-1)}$$

or

$$\frac{c''}{c''+e} = \frac{(\alpha'-1)c'}{(\alpha''-1)(c'+d)}$$

From which

$$c'' = \frac{e\left[\dfrac{(\alpha'-1)\ c'}{(\alpha''-1)(c'+d)}\right]}{1-\left[\dfrac{(\alpha'-1)\ c'}{(\alpha''-1)(c'+d)}\right]}$$

$$c'' = \frac{e}{\left[\dfrac{(\alpha''-1)(c'+d)}{(\alpha'-1)\ c'}\right]-1} \quad (13)$$

Similarly

$$c''' = \frac{f}{\left[\dfrac{(\alpha'''-1)(c'+d)}{(\alpha'-1)\ c'}\right]-1} \quad (14)$$

and so on for the various binaries.

Since $c = c' + c'' + c''' \text{---}$

$$c = c' + \frac{e}{\left[\dfrac{(\alpha''-1)(c'+d)}{(\alpha'-1)\ c'}\right]-1} + \frac{f}{\left[\dfrac{(\alpha'''-1)(c'+d)}{(\alpha'-1)\ c'}\right]-1} \quad (15)$$

Also

$$(L/D)_m = (L'/D')_m = \frac{1}{(\alpha'-1)X'_F} = \frac{1}{\left[\dfrac{c'\ \ (\alpha'-1)}{(c'+d)}\right]}$$

$$= \frac{c'+d}{(\alpha'-1)c'} \quad (16)$$

or similarly

$$(L/D)_m = \frac{c''+e}{(\alpha''-1)c''}$$

To solve for (L/D)m for the (c/d,e,f---) mixture

with liquid feed, various values of c′ are substituted by trial and error in equation (15) to obtain the correct value of c′ to satisfy the equation. This value of c′ is then used in equation (16) to obtain (L′/D′)m which is numerically equal to (L/D)m for the (c/d,e,f---) mixture.

(c/d,e,f---) Mixtures, Feed = Dew Point Vapor—Just as in the previous consideration, for the various binaries it is postulated that

$$\left(\frac{L}{D}\right)_m = \left(\frac{L}{C}\right)_m = \left(\frac{L'}{C'}\right)_m = \left(\frac{L''}{C''}\right)_m = \left(\frac{L'''}{C'''}\right)_m = \text{-------} \quad (17)$$

For any two component separation for which the feed is dew point vapor

$$\left(\frac{L}{D}\right)_m = \frac{1}{\alpha - 1}\left[\frac{\alpha X_D}{X_F} - \frac{(1 - X_D)}{(1 - X_F)}\right] - 1 \quad (5)$$

For complete separations

$$\left(\frac{L}{D}\right)_m = \frac{\alpha}{(\alpha - 1)X_F} - 1$$

For the above specified binaries

$$\frac{\alpha'}{(\alpha' - 1)X'_F} - 1 = \frac{\alpha''}{(\alpha'' - 1)X''_F} - 1 = \frac{\alpha'''}{(\alpha''' - 1)X_F'''} - 1 = \text{-----}$$

$$\frac{\alpha'}{(\alpha' - 1)X'_F} = \frac{\alpha''}{(\alpha'' - 1)X''_F} = \frac{\alpha'''}{(\alpha''' - 1)X_F'''} = \text{------}$$

$$X''_F = \frac{(\alpha'')(\alpha' - 1)}{(\alpha')(\alpha'' - 1)} X'_F$$

$$\frac{c''}{c'' + e} = \frac{\alpha''}{\alpha'} \cdot \frac{(\alpha' - 1)}{(\alpha'' - 1)} \cdot \frac{c'}{(c' + d)}$$

$$c'' = \frac{e\left[\frac{\alpha''}{\alpha'} \cdot \frac{(\alpha' - 1)}{(\alpha'' - 1)} \cdot \frac{c'}{(c' + d)}\right]}{1 - \left[\frac{\alpha''}{\alpha'} \cdot \frac{(\alpha' - 1)}{(\alpha'' - 1)} \cdot \frac{c'}{(c' + d)}\right]}$$

$$c'' = \frac{e}{\left[\frac{(c' + d)}{c'} \cdot \frac{(\alpha'' - 1)}{(\alpha' - 1)} \cdot \frac{\alpha'}{\alpha''} - 1\right]} \quad (18)$$

Similarly

$$c''' = \frac{f}{\frac{(c' + d)}{c'} \cdot \frac{(\alpha''' - 1)}{(\alpha' - 1)} \cdot \frac{\alpha'}{\alpha'''} - 1} \quad (19)$$

and so on for the various binaries.

Since $c = c' + c'' + c'''$ ------

$$c = c' + \frac{e}{\frac{(c' + d)}{(c')} \cdot \frac{(\alpha'' - 1)}{(\alpha' - 1)} \cdot \frac{\alpha'}{\alpha''} - 1} + \frac{f}{\frac{(c' + d)}{c'} \cdot \frac{(\alpha''' - 1)}{(\alpha' - 1)} \cdot \frac{\alpha'}{\alpha'''} - 1} \quad (20)$$

also

$$\left(\frac{L}{D}\right)_m = \left(\frac{L'}{D'}\right)_m = \frac{\alpha'}{(\alpha' - 1)X_F} - 1 = \frac{\alpha'}{(\alpha' - 1)\left[\frac{c'}{(c' + d)}\right]} - 1$$

$$= \frac{\alpha'(c' + d)}{(\alpha' - 1)c'} - 1 \quad (21)$$

or similarly

$$(L/D)_m = \frac{\alpha''(c'' + e)}{(\alpha'' - 1)c''} - 1$$

To solve for (L/D)m for the (c/d,e,f ------) mixture with vapor feed, various values of c′ are substituted by trial and error in equation (20) to obtain the correct value for c′ to satisfy the equation. This value of c′ is then used in equation (21) to obtain (L′/D′)m which is numerically equal to (L/D)m for the (c/d,e,f ----) mixture.

(---- a, b, c/d) Mixture, Feed = Bubble Point Liquid—Consider the complete separation of an ideal system of the (--- a, b, c/d) type with bubble point liquid feed.

Resolve the (--- a, bc/d) mixture into binaries as follows:

Part of d (say d′) with all of c
Part of d (say d″) with all of b
Part of d (say d‴) with all of a

Using the minimum reflux operating line in the bottom of the column $(\overline{L}/W)$, for each of the above binaries there is a minimum reflux ratio $(\overline{L}/W)$ required to completely separate the binary as follows:

$(\overline{L}'/W')m$ for c,d′ binary = $(\overline{L}/d')m$
$(\overline{L}''/W'')m$ for b,d″ binary = $(\overline{L}'/d'')m$
$(\overline{L}'''/W''')m$ for a,d‴ binary = $(\overline{L}''/d''')m$
and so on
(Note that for complete separation
$W' = d'$, $W'' = d''$, $W''' = d'''$ and so on)

For the binaries as specified above

$$\left(\frac{\overline{L}}{W}\right)_m = \left(\frac{\overline{L}'}{W'}\right)_m = \left(\frac{\overline{L}''}{W''}\right)_m = \left(\frac{\overline{L}'''}{W'''}\right)_m = \text{-----} \quad \text{.....(22)}$$

For the complete separation of any two component system for which the feed is liquid at the bubble point

$$\left(\frac{\overline{L}}{W}\right)_m = \frac{\alpha}{(\alpha - 1)(1 - X_F)} \text{.....(23)}$$

Therefore

$$\frac{\alpha'}{(\alpha' - 1)(1 - X'_F)} = \frac{\alpha''}{(\alpha'' - 1)(1 - X''_F)} = \frac{\alpha'''}{(\alpha''' - 1)(1 - X'''_F)}$$

$$(1 - X''_F) = \frac{\alpha''(\alpha' - 1)(1 - X'_F)}{\alpha'(\alpha'' - 1)}$$

$$1 - \frac{b}{(b + d'')} = \frac{\alpha''(\alpha' - 1)}{\alpha'(\alpha'' - 1)}\left(1 - \frac{c}{c + d'}\right)$$

$$\frac{d''}{b + d''} = \frac{\alpha''(\alpha' - 1)d'}{\alpha'(\alpha'' - 1)(c + d')}$$

$$d'' = \frac{b\left[\frac{\alpha''(\alpha' - 1)d'}{\alpha'(\alpha'' - 1)(c + d')}\right]}{1 - \left[\frac{\alpha''(\alpha' - 1)d'}{\alpha''(\alpha'' - 1)(c + d')}\right]}$$

$$d'' = \frac{b}{\left[\frac{\alpha'(\alpha'' - 1)(c + d')}{\alpha''(\alpha' - 1)d'}\right] - 1} \text{.....(24)}$$

Similarly

$$d''' = \frac{a}{\left[\frac{\alpha'(\alpha''' - 1)(c + d')}{\alpha'''(\alpha' - 1)d'}\right] - 1} \text{.....(25)}$$

Since $d = d' + d'' + d''' + \text{.....}$

$$d = d' + \frac{b}{\left[\frac{\alpha'(\alpha'' - 1)(c + d')}{\alpha''(\alpha' - 1)d'}\right] - 1} + \frac{a}{\left[\frac{\alpha'(\alpha''' - 1)(c + d')}{\alpha'''(\alpha' - 1)d'}\right] - 1} + \text{-----} \quad \text{.....(26)}$$

Also

$$\left(\frac{\overline{L}}{W}\right)_m = \left(\frac{\overline{L}'}{W'}\right)_m = \frac{\alpha'}{(\alpha' - 1)(1 - X'_F)} = \frac{\alpha'}{(\alpha' - 1)[1 - c/(c + d')]}$$

$$= \frac{\alpha'(c + d')}{(\alpha' - 1)d'} \text{.....(27)}$$

or to convert to the (L/D) form

$$\overline{L} = \frac{W \times \overline{L}'}{W'} = \frac{d(c+d')\alpha'}{d'(\alpha'-1)}$$

$L = \overline{L} - F$ and $D = (\text{---} + a + b + c.)$

$$\left(\frac{L}{D}\right)_m = \frac{(d/d')(c+d')[\alpha'/(\alpha'-1)] - F}{(\text{---} + a + b + c.)} \quad \text{.....(28)}$$

Or similarly

$$\left(\frac{L}{D}\right)_m = \frac{(d/d'')(b+d'')[\alpha''/(\alpha''-1)] - F}{(\text{----} + a + b + c.)}$$

To solve for (L/D)m for the (--- a, b, c/d) mixture with liquid feed, various values of d′ are substituted by trial and error in equation (26) to obtain the correct value of d′ to satisfy the equation. This value of d′ is then used in equation (27) to obtain (L′/W′)m which is numerically equal to (L/W)m for the (--- a, b, c/d) mixture; (L/D)m for the column can then be computed from the column material balance, unless it is preferred to compute (L/D)m directly from equation (28). It is to be noted that (L/D)m ≠ (L′/D′)m ≠ (L″/D″)m ≠ ---.

(---- a, b, c/d) Mixture, Feed = Dew Point Vapor—Just as in the previous case, it is postulated that

$$\left(\frac{\overline{L}}{W}\right)_m = \left(\frac{\overline{L}}{d}\right)_m = \left(\frac{\overline{L'}}{d'}\right)_m = \left(\frac{\overline{L''}}{d''}\right)_m = \left(\frac{\overline{L'''}}{d'''}\right)_m = \text{.....(29)}$$

For the complete separation of any two component system for which the feed is dew point vapor

$$\left(\frac{\overline{L}}{W}\right)_m = \frac{1}{1 - 1/[\alpha - X_F(\alpha - 1)]} \quad \text{.....(30)}$$

For the above specified binaries

$$\frac{1}{1-1/[\alpha' - X_F(\alpha'-1)]} = \frac{1}{1-1/[\alpha'' - X''_F(\alpha''-1)]} = \frac{1}{1-1/[\alpha''' - X'''_F(\alpha'''-1)]} =$$

$$X''_F = X'_F \frac{(\alpha'-1)}{(\alpha''-1)} + \frac{(\alpha''-\alpha')}{(\alpha''-1)}$$

$$\frac{b}{b+d''} = \frac{c}{(c+d')}\frac{(\alpha'-1)}{(\alpha''-1)} + \frac{(\alpha''-\alpha')}{(\alpha''-1)}$$

$$d'' = \frac{b\left\{1 - \left[\frac{(\alpha'-1)c}{(\alpha''-1)(c+d')} + \frac{(\alpha''-\alpha')}{(\alpha''-1)}\right]\right\}}{\frac{(\alpha'-1)c}{(\alpha''-1)(c+d')} + \frac{(\alpha''-\alpha')}{(\alpha''-1)}}$$

$$d'' = b\left\{\frac{1}{\left[\frac{(\alpha'-1)c}{(\alpha''-1)(c+d')} + \frac{(\alpha''-\alpha')}{(\alpha''-1)}\right]} - 1\right\}$$

$$d'' = b\left[\frac{(\alpha''-1)(c+d')}{(\alpha''-1)c + (\alpha''-\alpha')d'} - 1\right] \quad \text{.....(31)}$$

Similarly

$$d''' = a\left[\frac{(\alpha'''-1)(c+d')}{(\alpha'''-1)(c) + (\alpha'''-\alpha')d'} - 1\right] \quad (32)$$

Since $d = d' + d'' + d''' + \text{----}$

$$d = d' + b\left[\frac{(\alpha''-1)(c+d')}{(\alpha''-1)c + (\alpha''-\alpha')d'} - 1\right] + a\left[\frac{(\alpha'''-1)(c+d')}{(\alpha'''-1)c + (\alpha'''-\alpha')d'} - 1\right] + \text{....(33)}$$

Also

$$\left(\frac{\overline{L}}{W}\right)_m = \left(\frac{\overline{L'}}{W'}\right)_m = \frac{1}{1-1/[\alpha' - X'_F(\alpha'-1)]} \quad \text{...(34)}$$

or to convert to the (L/D) form

Since $L = \overline{L}$ and $D = (\text{---} + a + b + c)$

$$(L)m = (\overline{L})m = \left(\frac{WL'}{W'}\right)_m = \frac{d}{1 - \left\{\frac{1}{\alpha' - \left[\frac{c(\alpha'-1)}{(c+d')}\right]}\right\}}$$

$$\left(\frac{L}{D}\right)_m = \frac{\left\{\frac{d}{1 - \left\{\frac{1}{\alpha' - \left[\frac{c(\alpha'-1)}{(c+d')}\right]}\right\}}\right\}}{(\text{----} a + b + c)}$$

$$= \frac{d}{(\text{---} a + b + c)\left\{1 - \left[\frac{(c+d')}{\alpha'(c+d') - c(\alpha'-1)}\right]\right\}}$$

$$= \frac{d(\alpha'c + \alpha'd' - \alpha'c + c)}{(\text{---} a + b + c)(\alpha'c + \alpha'd' - \alpha'c + c - c - d')}$$

$$\left(\frac{L}{D}\right)_m = \frac{d(\alpha'd' + c)}{d'(\text{---} + a + b + c)(\alpha' - 1)} \quad \text{.....(35)}$$

Or similarly

$$(L/D)m = \frac{d(\alpha''d'' + b)}{d''(\text{---} + a + b + c.)(\alpha'' - 1)}$$

To solve for (L/D)m for the (--- a, b, c/d) mixture with vapor feed, various values of d′ are substituted by trial and error in equation (33) to obtain the correct value of d′ to satisfy the equation. This value of d′ is then used in equation (34) to obtain (L̄/W)m for the (---- a, b, c/d) mixture; (L/D)m for the column can be computed by material balance, unless it is preferred to compute (L/D)m directly from equation (35). Note that (L/D)m ≠ (L′/D′)m ≠ (L″/D″) ≠ ---.

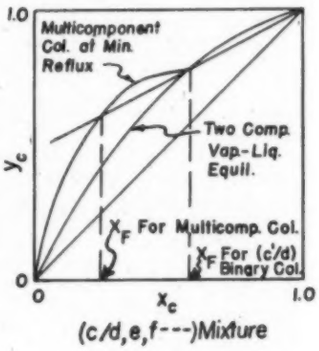


FIGURE 4

Typical Phase Diagrams

A typical y-x diagram for component c (the light key) is given in Figure 4 for c with d only and for c present in the (c/d, e, f ---) mixture in a column operating at minimum reflux. Note that for the condition of minimum reflux there is a "pinch" section of infinite plates in the upper part of the column where the concentrations of all components heavier than the heavy key are essentially zero. Thus, with only the two key components (c and d) present the y-x curve for component c in the multicomponent column operating at minimum reflux coincides with the y-x equilibrium curve for the (c, d) mixture; these two curves coicide from the "pinch" point, the composition of which is

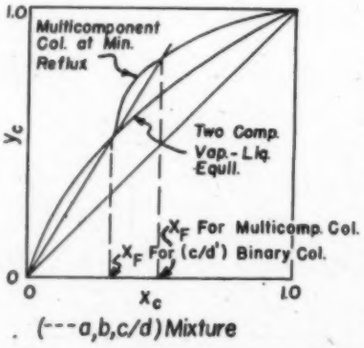


FIGURE 5

Example Calculations

EXAMPLE I. *(c/d, e) Mixture, Feed = Bubble Point Liquid.*

Compute (L/D)m for the complete separation of the following mixture:

	X_F	α
c	0.3	2.0
d	0.3	1.0
e	0.4	0.5

$$c = c' + \frac{e}{\left[\frac{(\alpha''-1)(c'+d)}{(\alpha'-1)c'} - 1\right]} = c' + \frac{0.4}{\left[\frac{(4-1)(c'+0.3)}{(2-1)c'} - 1\right]} \quad \ldots\ldots (15)$$

$$= c' + \frac{0.4}{\left[\frac{3(c'+0.3)}{c'} - 1\right]}$$

For First Trial, assume $c' = 0.25$

$$0.3 \overset{?}{=} 0.25 + \frac{0.4}{\left[\frac{3(0.25+0.3)}{0.25} - 1\right]} = 0.25 + 0.071 = 0.321 \neq 0.3$$

Try $c' = 0.232$

$$0.3 \overset{?}{=} 0.232 + \frac{0.4}{\left[\frac{3(0.232+0.3)}{0.232}\right]} = 0.232 + 0.068 = 0.300 = 0.3$$

Using $c' = 0.232$

$$(L/D)m = \frac{c'+d}{(\alpha'-1)c'} = \frac{0.232+0.3}{(2-1)0.232} = \underline{\underline{2.293}} \quad \ldots\ldots (16)$$

EXAMPLE II. *(c/d, e) Mixture, Feed = Dew Point Vapor.*

Compute (L/D)m for the complete separation of the following mixture:

	X_F	α
c	0.3	2.0
d	0.3	1.0
e	0.4	0.5

$$c = c' + \frac{e}{\left[\frac{\alpha'(\alpha''-1)(c'+d)}{\alpha''(\alpha'-1)c'} - 1\right]} = c' + \frac{0.4}{\left[\frac{2(4-1)(c'+0.3)}{4(2-1)c'} - 1\right]} = c' + \frac{0.4}{\left[\frac{6(c'+0.3)}{4c'} - 1\right]}$$

$$\ldots\ldots (20)$$

For First Trial, assume $c' = 0.20$

$$0.3 \overset{?}{=} 0.20 + \frac{0.4}{\left[\frac{6(0.2+0.3)}{4(0.20)} - 1\right]} = 0.20 + 0.145 = 0.345 \neq 0.3$$

Try $c' = 0.1718$

$$0.3 \overset{?}{=} 0.1718 + \frac{0.4}{\left[\frac{6(0.1718+0.3)}{4(0.1718)} - 1\right]} = 0.1718 + 0.1282 = 0.3000 = 0.3$$

Using $c' = 0.1718$

$$(L/D)m = \frac{\alpha'(c'+d)}{(\alpha'-1)c'} - 1 = \frac{2(0.1718+0.3)}{(2-1)\,0.1718} - 1 = \underline{\underline{4.49}}$$

$$\ldots\ldots (21)$$

EXAMPLE III. *(b, c/d) Mixture, Feed = Bubble Point Liquid.*

Compute (L/D)m for the complete separation of the following mixture:

	X_F	α
b	0.4	4
c	0.3	2
d	0.3	1

$$d = d' + \frac{b}{\left[\frac{\alpha'(\alpha''-1)(c+d')}{\alpha''(\alpha'-1)d'} - 1\right]} = \frac{0.4}{\left[\frac{2(4-1)(0.3+d')}{4(2-1)d'} - 1\right]} = d' + \frac{0.4}{\left[\frac{6(0.3+d')}{4(d')} - 1\right]} \quad \ldots (26)$$

For First Trial, assume $d' = 0.20$

$$0.3 \overset{?}{=} 0.20 + \frac{0.4}{\left[\frac{6(0.3+0.2)}{4(0.2)} - 1\right]} = 0.20 + 0.145 = 0.345 \neq 0.3$$

Try $d' = 0.1718$

$$0.3 \overset{?}{=} 0.1718 + \frac{0.4}{\left[\frac{6(0.3+0.1718)}{4(0.1718)} - 1\right]} = 0.1718 + 0.1282 = 0.3000 = 0.3$$

Using $c' = 0.1718$

$$(L/D)m = \frac{(d/d')[\alpha'/(\alpha'-1)](c+d') - F}{b+c} \quad \ldots\ldots (28)$$

$$= \frac{(0.3/0.1718)[2/(2-1)](0.3+0.1718) - 1}{0.4+0.3}$$

$$= \underline{\underline{0.924}}$$

EXAMPLE IV. *(b, c/d) Mixture, Feed = Dew Point Vapor.*

Compute (L/D)m for the complete separation of the following mixture:

	X_F	α
b	0.4	4
c	0.3	2
d	0.3	1

$$d = d' + b\left\{\left[\frac{(\alpha''-1)(c+d')}{c(\alpha''-1) + d'(\alpha''-\alpha')}\right] - 1\right\} \quad \ldots\ldots (33)$$

$$= d' + 0.4\left\{\left[\frac{(4-1)(0.3+d')}{0.3(4-1) + d'(4-2)}\right] - 1\right\}$$

$$d = d' + 0.4\left[\frac{3(0.3+d')}{0.9+2d'} - 1\right]$$

For First Trial, assume $d' = 0.25$

$$d = 0.25 + 0.4\left[\frac{3(0.3+0.25)}{0.9+2(0.25)} - 1\right] = 0.25 + 0.071 = 0.321 \neq 0.3$$

Try $d' = 0.232$

$$d = 0.232 + 0.4\left[\frac{3(0.3+0.232)}{0.9+2(0.232)} - 1\right] = 0.232 + 0.068 = 0.300 = 0.3$$

Using $d' = 0.232$

$$(L/D)m = \left(\frac{d}{d'}\right)\left[\frac{\alpha'd'+c}{(b+c)(\alpha'-1)}\right] = \left(\frac{0.3}{0.232}\right)\left[\frac{2(0.232)+0.3}{(0.4+0.3)(2-1)}\right] = \underline{\underline{1.411}}$$

$$\ldots\ldots (35)$$

$c'/(c' + d)$ as specified above for the (c', d) binary, on up to $X_c = Y_c = 1.0$.

A typical y-x diagram for component c (the light key) is given in Figure 5 for c with d only and for c present in the (--- + a,b,c/d) mixture in a column operating at minimum reflux. Note that for the condition of minimum reflux there is a "pinch" section of infinite plates in the lower part of the column where the concentrations of all components lighter than the light key are essentially zero. With only the two key components (c and d) present the y-x curve for component c in the multicomponent column operating at minimum reflux coincides with the y-x equilibrium curve for the (c,d) mixtures; these two curves coincide from the "pinch" point, the composition of which is $d'/(c + d')$ as specified above for the (c, d') binary, on down to $X_c = Y_c = 0.0$.

Accuracy of Method

Since the fundamental hypothesis of this method appears to be sound, it is believed that minimum reflux ratios for multicomponent separations of the types considered here can be computed as accurately as for binary separations.

Table 5 presents a comparison of values determined by Colburn's method and by plate-to-plate calculations, as reported by Colburn[3], with those determined by this method for multicomponent separations. The agreement between the three methods is almost perfect.

Acknowledgement

The authors wish to thank The Dow Chemical Company for permission to publish this paper.

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Nomenclature

a, b = refers to components lighter than light key component; numerically equal to moles per mole of multicomponent column feed (F = 1.0).

c = refers to light key component; numerically equal to moles per mole of multicomponent column feed (F = 1.0).

c' = refers to the portion of light key in a binary consisting of all of d and some of c.

c'' = refers to the portion of light key in a binary consisting of all of e and some of c.

c''' = refers to the portion of light key in a binary consisting of all of f and some of c.

d = refers to heavy key component; numerically equal to moles per mole of multicomponent column feed (F = 1.0).

d' = refers to the portion of heavy key in a binary consisting of all of c with some of d.

d'' = refers to the portion of heavy key in a binary consisting of all of b with some of d.

d''' = refers to the portion of heavy key in a binary consisting of all of a with some of d.

e, f = refers to components heavier than the heavy key component; numerically equal to moles per mole of multicomponent column feed (F = 1.0).

D = moles of overhead distillate per unit of time for the multicomponent column.

D' = moles of overhead distillate per unit of time for the (c', d) binary derived from a (c/d, e, f ---) mixture, or for the (c, d') binary derived from a (--- a, b, c/d) mixture.

D'' = moles of overhead distillate per unit of time for the (c'', e) binary derived from a (c/d, e, f, ---) mixture, or for the (b, d'') binary derived from a (--- a, b, c/d) mixture.

D''' = moles of overhead distillate per unit of time for the (c''', f) binary derived from a (c/d, e, f ---) mixture, or for the (a, d''') binary derived from a (--- a, b, c/d) mixture.

F = moles of feed per unit of time to the multicomponent column.

L = moles of reflux (above the feed) per unit of time to the multicomponent column.

$\overline{L}$ = moles of reflux (below the feed) per unit of time to the multicomponent column.

L', $\overline{L}'$ = moles of reflux per unit of time above and below the feed respectively for the (c', d) binary or for the (c, d') binary.

L'', $\overline{L}''$ = moles of reflux per unit of time above and below the feed respectively for the (c'', e) binary or for the (b, d'') binary.

L''', $\overline{L}'''$ = moles of reflux per unit of time above and below the feed respectively for the (c''', f) binary or for the (a, d''') binary.

V, $\overline{V}$ = moles of vapor per unit of time above and below the feed respectively.

W = moles of bottom product per unit of time for the multicomponent column.

W' = moles of bottom product per unit of time for the (c', d) binary or for the (c, d') binary.

W'' = moles of bottom product per unit of time for the (c'', e) binary or for the (b, d'') binary.

W''' = moles of bottom product per unit of time for the (c''', f) binary or for the (a, d''') binary.

X_D = mole fraction light key in distillate.

X_F = mole fraction of light key in feed.

X_W = mole fraction of light key in bottoms.

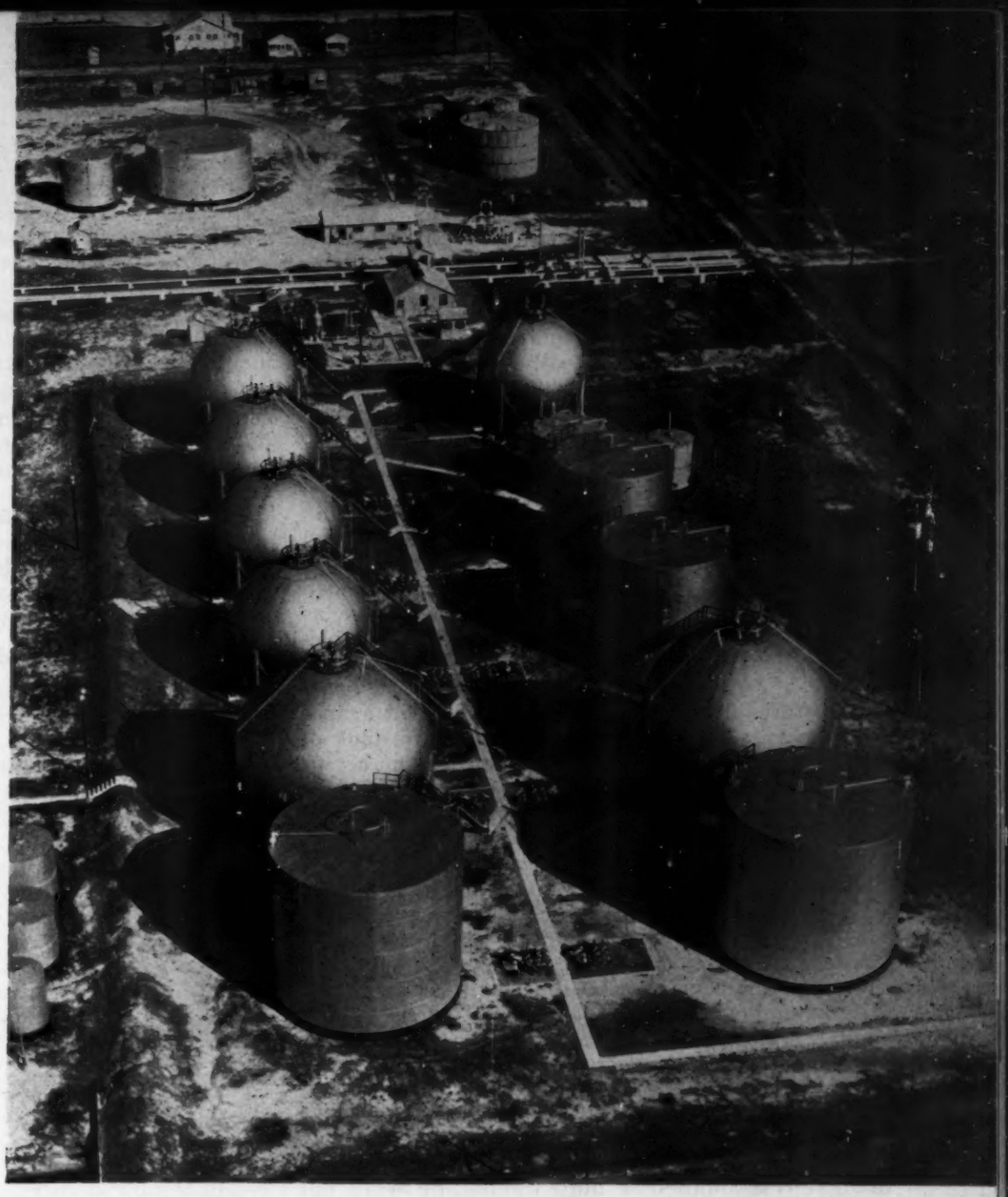
α = relative volatility of any component with respect to a less volatile component.

α' = relative volatility of component c with respect to component d.

α'' = relative volatility of component b with respect to component d for (-- a, b, c/d) mixtures; or of component c with respect to component e for (c/d, e, f ---) mixtures.

α''' = relative volatility of component a with respect to component d for (--- a, b, c/d) mixtures; or of component c with respect to component f for (c/d, e, f --) mixtures.

Subscript m = refers to the condition of minimum reflux.



Storage tanks at a South Texas cycling plant. Included are one 10,000-barrel and two 5000-barrel spheres for 80-pound pressure, and one 10,000-barrel and three 5000-barrel spheres for 25-pound pressure.

Storage
Of Volatile Petroleum Products

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THE atomic bomb has not altered natural laws; the principles of evaporation are immutable. Therefore each succeeding paper on the storage of petroleum products is in part reiteration of the facts on which all scientific storage methods are based. This repetition is justified if it brings the reader back to fundamentals from which he has strayed. Certainly a clear mental picture of the phenomenon of evaporation is essential to an understanding of the methods of reducing storage losses.

The following discussion applies strictly to homogeneous liquids, but in principle is applicable to petroleum products too.

The molecules composing a liquid are in rapid motion at rates which depend entirely upon their temperatures. If there is space above the liquid some of the more rapidly moving molecules constantly shoot out into it. The number which leave the liquid per square inch of surface per second, and their speed, are determined by the liquid surface tempera-

ture. The warmer the liquid, the faster the molecules move and the more of them leave per unit of time. This process of separation of molecules from their liquid is evaporation.

If a liquid is put into a closed vessel free from air (a vacuum) the molecules which evaporate are confined within the walls. They hit each other, the sides, and the roof, and rebound, and some return to the liquid. This return of vapor molecules to the parent liquid is condensation. Eventually, if no heat is added to or taken from the container, a condition is reached in which the molecules leave and return at the same rate. Then the vapor is said to be saturated. The rates of evaporation and condensation are equal. Evaporation continues, but evaporation losses cease.

Vapor becomes saturated almost instantly if liquid be put into a vacuum tank, but if the tank be filled with air when the liquid is introduced, and the air and liquid do not unite chemically, diffusion is much slower. The reduced rate may be thought of as caused by collisions between the air and vapor molecules. Although the air delays the saturation, it in no way affects the final vapor density. At a given temperature the same amount of liquid will evaporate into an air-filled tank as into a vacuum tank of the same size. Each cubic foot of space, whether or not air be present, will eventually contain a specific number of vapor molecules moving at a definite average velocity.

Some of these moving molecules are continually hitting the walls of the container and rebounding. This bombardment causes pressure, known as the *vapor pressure* of the liquid, which is a function of the temperature only.

The air molecules strike the vessel walls practically as they would if the vapor were not present. A similar statement is true of the vapor molecules. Therefore, the total pressure in the vapor space is the sum of the vapor pressure and the pressure which the air would exert if it alone filled the space occupied by the air and vapor.

If several liquids and gases which do not mutually dissolve one another or unite chemically were put into a tank, each would exert the same pressure that it would if it alone were present, and the total pressure would be the sum of their separate or partial pressures. However, if liquids and gases which do mutually dissolve one another, or unite chemically, were put into the tank, the total pressure would not be the sum of their separate pressures. The vapor pressure of a solution is always less than the sum of the vapor pressures of its components.

Evidently, at a given temperature, more liquid will evaporate into a large space than into a small one but, after saturation, the pressures and also the densities in the spaces will be equal.

Therefore, if the temperature remains constant, the pressure of a saturated vapor in the presence of its liquid cannot be changed by making the vapor space larger or smaller. If there is no vapor space—that is, if the roof of the tank is kept in contact with the liquid—no vapor can form but the pressure upward against the roof is just the same as if vapor could form. If the roof is raised slowly off of the liquid surface, or the liquid level lowered, keeping the temperature constant, sufficient liquid will evaporate to maintain the pressure; if the liquid space be decreased slowly, without a change of temperature, some of the vapor will condense, leaving the pressure unchanged.

If so little liquid be put into a tank that it all evaporates, the vapor is unsaturated (or superheated) because more liquid would evaporate if it were present. If the unsaturated vapor is cooled it will be found that, at some temperature, liquid will appear on the tank bottom. The vapor will then be saturated. Likewise, if unsaturated vapor is compressed sufficiently, liquid will form and the vapor be saturated. In both cases there are satisfactory mental pictures of what happens.

In the unsaturated state the molecules are widely separated and moving rapidly. As the temperature falls the molecules move more and more slowly until finally their attraction for each other overcomes their kinetic energy, and by uniting they become liquid.

In the second case the increasing pressure forces the molecules closer and closer together until cohesion unites some of them as liquid. When liquid appears the vapor is saturated; it contains all the molecules it can hold at the existing temperature.

According to Law

Air and other gases are vapors far removed from their saturation states. For them changes in pressure, temperature, and volume vary in accordance with Boyle's and Charles' law, which states that $PV/T = K$, in which P is the absolute pressure (gauge pressure plus atmospheric pressure), V is the vapor volume, T is the absolute temperature (reading of a Fahrenheit thermometer plus 460°), and K is a constant. The relations between the pressures and temperatures of saturated vapors are more complex, and it is customary to refer to tables or charts to obtain them. Each liquid has a specific vapor pressure versus temperature curve. See Figure 1.

For the special case of air changing volume adiabatically (without the addition or subtraction of heat) the product $PV^{1.4}$ is constant, the exponent 1.4 being the ratio of the specific heat of air at constant pressure to the specific heat of air at constant volume.

If a liquid is put into an uncovered tank and heated until its vapor pressure equals atmospheric pressure, it will begin to vaporize visibly (will agitate the surface), and be said to boil. While boiling is commonly understood to be at atmospheric pressure, it may be at higher and lower pressures. Water at sea level boils at higher temperature than on a mountain top. Precisely stated, a liquid boils whenever its vapor pressure equals the pressure to which the liquid surface is subjected. While a liquid is boiling at constant pressure its temperature does not change, but heat must be continuously applied. The heat required to change a liquid into vapor at boiling temperature is called the *heat of vaporization.*

Vaporization, whether by evaporation or boiling, requires heat. For example, heat is taken from the atmosphere when water is allowed to evaporate from an open vessel, or when oil is evaporated in a storage tank. Therefore, evaporation is a cooling process. The greater the quantity of heat used to raise a liquid to the boiling temperature the less is the heat necessary to convert it into vapor by boiling.

Otherwise expressed, for a given liquid an increase in the boiling temperature (and pressure) means a reduced heat of vaporization. Less heat is required to change water at boiling temperature at sea level into vapor than is required to change an equal quantity into vapor at boiling temperature on a mountain top. At the critical temperature (and critical pressure) the heat of vaporization is zero.

The critical pressure is the highest pressure which a liquid can develop. Above the critical pressure and temperature a substance can exist only as a gas.

Evaporation of Petroleum Products

The foregoing discussion of the evaporation and boiling of homogeneous liquids applies in a general way to petroleum and its liquid derivatives. However, since crude oil consists of several hydrocarbons together with some oxygen, nitrogen, and sulphur, its evaporation conditions are very complicated. Some of the components are gases, some liquids, and some is true of gasoline. Therefore, for both crude oil and gasoline in storage the vapor pressure is not only a function of temperature, but also, to some degree, of the size of the vapor space. Evaporation reduces both *volume* and *quality*. The relation of the volume and quality of gasoline, as evaporation progresses, is the basis of the Chenicek and Whitman method of determining standing storage evaporation losses, which was published in the report of the 11th Annual Meeting of the American Petroleum Institute, Vol. II, No. 75, Page 4 (1930).

When gasoline is stored in partly-filled tanks the

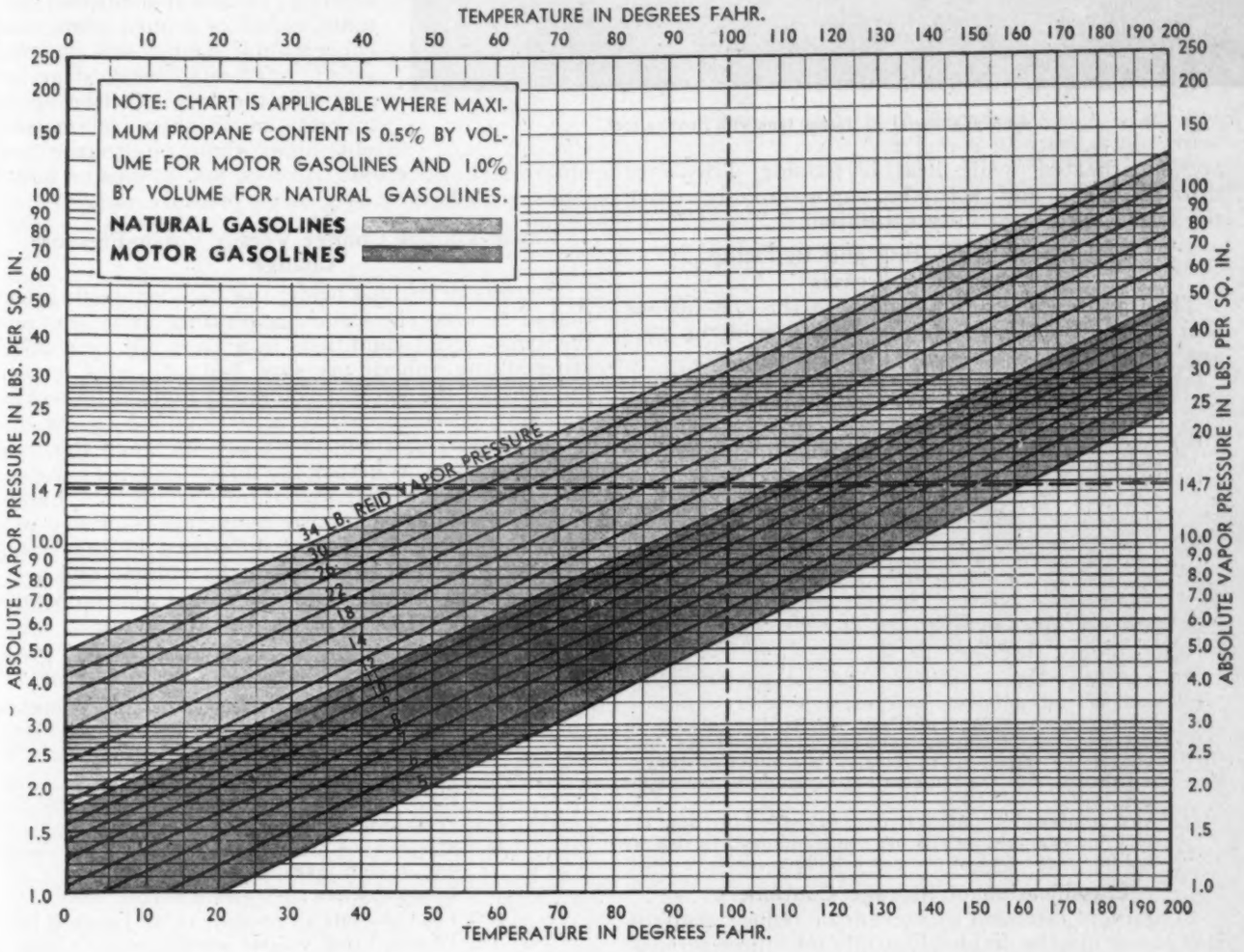

TEMPERATURE IN DEGREES FAHR.
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
NOTE: CHART IS APPLICABLE WHERE MAXIMUM PROPANE CONTENT IS 0.5% BY VOLUME FOR MOTOR GASOLINES AND 1.0% BY VOLUME FOR NATURAL GASOLINES.
NATURAL GASOLINES
MOTOR GASOLINES
ABSOLUTE VAPOR PRESSURE IN LBS. PER SQ. IN.
250 200 150 100 90 80 70 60 50 40 30 25 20 14.7 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.5 2.0 1.5 1.0
34 LB. REID VAPOR PRESSURE
30
26
22
18
14
12
10
8
6
4

FIGURE 1

Chart showing Reid Vapor Pressures for typical motor gasoline and natural gasolines.

solids when in their pure states. They are present in such a manner that oil in storage stratifies to some extent with the most volatile portions at the top. These lighter fractions evaporate first, and the heavier ones follow at higher temperatures. The previous remarks about the vapor pressures of solutions make obvious the difficulty of determining the vapor pressure of crude oil from known characteristics and quantities of its components.

During evaporation or boiling, when both liquid and vapor are present, the composition of each is different at different temperatures, and neither has the same composition as the virgin liquid. The same temperature in the vapor space is not uniform. The heat from the sun is applied to the roof and sides and passes downward and laterally to reach the oil surface. The metal absorbs heat, and by radiation, and conduction, some of it is transferred through the vapor to the liquid.

Since, by conduction, heat flows only from regions of higher to regions of lower temperature, there must be a temperature gradient from the roof downward during periods of rising atmospheric temperature. Because air and vapor are poor heat conductors they somewhat shield the liquid surface from the heat of the sun. The result is that the upper levels of vapor

An 80,000-barrel oil storage tank with floating roof.

are superheated while heat is passing downward through them, and only the vapor directly above the liquid surface is fully saturated.

Methods of Preventing and Reducing Evaporation Losses

This discussion leads logically to the conclusions that evaporation losses from volatile liquids in storage vessels may be prevented or reduced by:

(a) Allowing the vapor and air mixture to change volume, at constant or variable pressure. This is what breather, balloon and lifter roofs do.
(b) Allowing no vapor space. This is what floating roofs, and water displacement tanks do.
(c) Withstanding the combined liquid and vapor space pressures. This is done by spheroids, spheres, and pressure vessels of other types.
(d) Resisting not only the maximum internal pressure, but also the maximum internal partial vacuum, which is the difference between atmospheric pressure and the lowest vapor pressure. Spheres are able to do this; many of them can safely operate under a full vacuum.
(e) Insulating the tank from the sun's heat. Coverings of brick, water, cork, and other insulating or shading materials, do this.
(f) Cooling, refrigerating, and vapor recovery systems. Examples are sprays utilizing the cooling effects of evaporation; circulating systems to recondense and recover the vapors, or to circulate the liquid in storage and thus reduce the temperature variation at the liquid surface.
(g) Any combinations of (a), (b), (c), (d), (e) and (f) such, for example, as floating roofs equipped to rise, as do lifter roofs, and trap vapor if boiling occurs.

Classification of Storage Containers

Containers intended to prevent or reduce evaporation losses may be divided logically into three groups:

A—Liquid-volume-change tanks.
B—Vapor-volume-change tanks.
C—Pressure-change tanks.

Individual containers may combine the features of all of these groups, and also utilize various temperature-control devices.

The outstanding feature of Group A containers is their ability to adjust themselves to varying liquid volumes, always keeping their retaining surfaces *in contact* with the liquid. Their volume is always that of the liquid which they hold. All heat entering such tanks is expended in heating the liquid. Tanks equipped with floating roofs fall in this group. Although not commonly thought of as such, these roofs are really pressure devices, since through their use the liquid surface is subjected to atmospheric pressure, which the vapor pressure must exceed before vapor can form.

The predominant feature of Group B containers is their ability to adjust themselves to varying vapor volumes, either at constant or variable pressure. Tanks equipped with breather or balloon or lifter roofs are in this group.

The distinguishing feature of Group C tanks is their ability to keep the combined liquid and vapor volume constant by withstanding internal pressures developed under storage conditions. Conventional storage tanks with vertical cylindrical shells, flat bottoms, coned or domed roofs, and conservation vents, fall in this group, but are so weak structurally that they are effective up to a very small pressure—usually not more than one ounce per square inch. Spheroids, spheres, and blimps or bullet tanks are effective over large pressure ranges.

Vapor-Volume Change Versus Vapor-Pressure Change

There is developed below the very interesting fact that, assuming the same temperature variations and the same initial conditions in a Group B tank operating at atmospheric pressure, and a Group C vessel, the ratio of the percent-volume change to the corresponding pressure change is 100 divided by the difference between atmospheric pressure and the final vapor pressure. Whether the final vapor pressure results from a small temperature change in a highly volatile gasoline, or a large temperature change in a very stable oil, makes no difference in this ratio. However, the actual values of the volume and pressure changes depend upon the initial and final temperatures and the character of the liquid.

t = Initial average Fahrenheit temperature of air and vapor, in both tanks.
T = Final average Fahrenheit temperature of air and vapor, in both tanks.
$t + 460$ = Initial absolute temperature.
$T + 460$ = Final absolute temperature.
p = Initial absolute vapor pressure.
P = Final absolute vapor pressure.
A = Atmospheric pressure = initial vapor space pressure in both tanks, absolute.
$A - p$ = Initial absolute air pressure in both tanks.
$A - P$ = Final absolute air pressure in the Group B tank.
I = Percent vapor volume increase in the Group B tank.
E = Pressure increase in the Group C tank.

According to Boyle's and Charles' law:

(a) $$I = 100\left[\left(\frac{A-p}{A-P}\right)\left(\frac{T+460}{t+460}\right)-1\right]$$

$$= \left(\frac{100}{A-P}\right)\left[(A-p)\left(\frac{T+460}{t+460}\right)-(A-P)\right]$$

(b) $$E = (A-p)\left[\left(\frac{T+460}{t+460}\right)-1\right]+(P-p)$$

$$= (A-p)\left(\frac{T+460}{t+460}\right)-(A-P)$$

(c) $$\frac{I}{E} = \frac{100}{A-P}$$ Q.E.D.

The ratio (I/E) clearly increases rapidly as the final vapor pressure, P, increases—that is, with in-

creasing volatility. Also the pressure increase for the Group C vessel is independent of the vapor-space volume, while the actual volume increase in the Group B vessel varies directly with the original vapor volume. It follows that, for storing highly volatile liquids, a pressure tank is much more effective than a volume-change tank operating at or near atmospheric pressure.

However, it should not be forgotten that part of the apparent advantage of the pressure tank is offset by the fact that a portion of the heat which enters the volume-change tank is expended in expanding the vapor space against atmospheric pressure. Otherwise expressed, the specific heat of gas at constant pressure is more than the specific heat at constant volume.

Filling and Storage Losses

For all types of containers the losses must occur either during filling or storage.

Group A Vessels. Provided boiling does not occur there can be no filling or storage losses from Group A vessels, except the windage and diffusion losses through and past the seals between moving and fixed parts, such as a floating roof and a tank shell, respectively. These losses are almost negligibly small from tanks equipped with modern floating roofs fitted to butt-welded shells. Furthermore, a moderate amount of boiling can occur with no appreciable vapor loss provided the floating roof is so shaped that it can rise on and retain the vapor without loss of stability.

Group B Vessels. A Group B vessel with an expansible roof operating at practically atmospheric pressure evidently will lose, during each filling after the first, at least an entire tank full of vapor less the capacity of the expansible element such, for example, as a lifter roof. Furthermore, after the tank is full of liquid, the lifter will be full of vapor, part of which will surely be forced out and lost if the temperature rises before emptying is begun.

The analytical determination of the proper lift for a given gasoline, tank, and climate, is difficult. The problem is somewhat like that of the steam engine. The lifter roof is the piston against which the expanding air-vapor mixture does work against atmospheric pressure; the tank shell is the cylinder; the sealing liquid or curtain corresponds to the packing rings; the gasoline to the water; the vapor to the steam; and the sun to the boiler. Every principle of thermodynamics is involved. The problem is more complicated than that of the engine because of the presence of air; because the heat is applied from above and must pass through the vapor to reach the liquid; and because every change of weather affects conditions in the tank.

Of the heat from the sun which falls on the tank, some is reflected, some is absorbed by the steel and raises its temperature, and the rest passes through the steel into the tank and is expended in

(a) Heating the air.
(b) Heating the vapor.
(c) Heating the gasoline.
(d) Evaporating the gasoline.
(e) Pushing the roof upward.

Evidently, the radiating properties of steel, the specific heats and thermal conductivities of steel, air, vapor, and gasoline, the retarding effect of air on the diffusion of vapor, and the effect of convection currents, are all factors to be considered.

Because of the complexity of this problem the required capacity of a lifter roof for a given tank, product in storage, and location, can best be determined by experiment. If field tests on vessels in service can correlate atmospheric temperature changes, tank proportions, quantity and character of liquid, vapor temperatures, oil-surface temperatures, and vapor-volume changes, the lift necessary to stop seasonal losses can be predicted with reasonable accuracy.

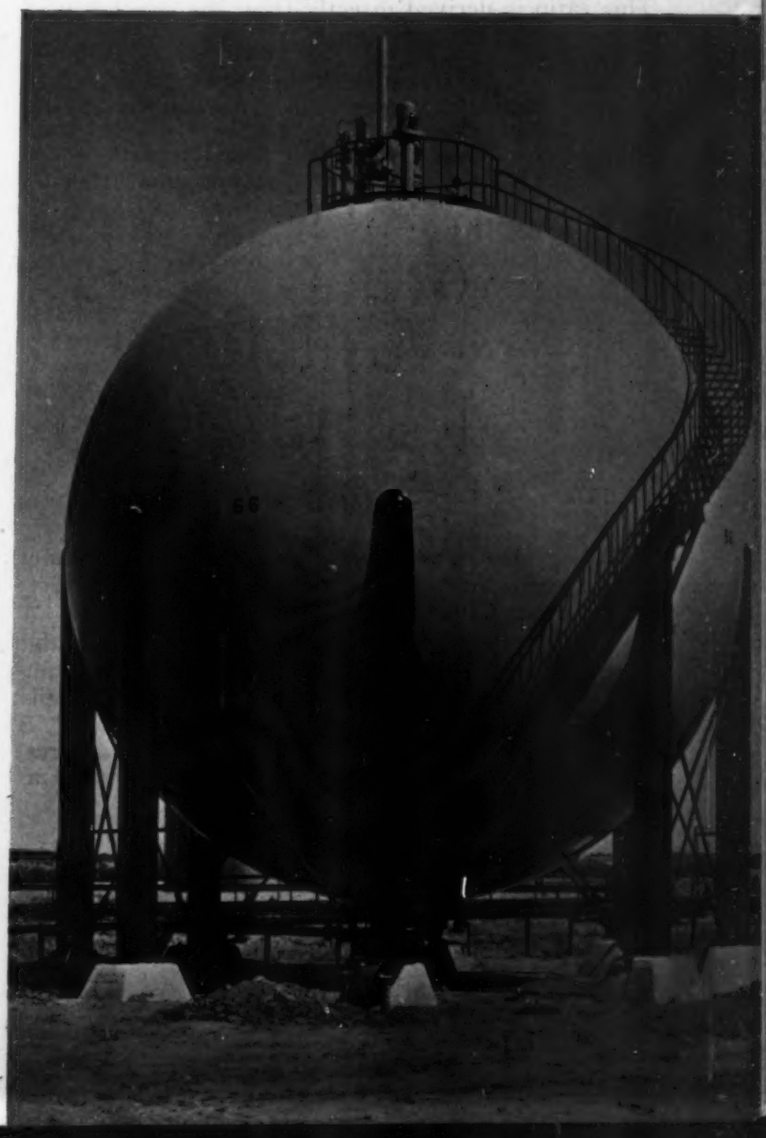
Continuous records on a vessel 49 feet-8 inches in diameter and 43 feet-10 inches high, of movement of a lifter roof, of atmospheric temperatures, and of temperatures at various elevations along the vertical axis of the tank when it contained only 4 feet-0 inches of gasoline, indicate that when a tank from 40 to 45 feet high is nearly empty, the rise of a lifter roof required to prevent daily losses for any particular season can be closely approximated on the assumption that:

(1) The average daily change in temperature in the vapor space is 1¼ times the atmospheric temperature change.
(2) The daily change in the temperature of the gasoline surface is 1/10 of the atmospheric temperature change.
(3) The base oil surface temperature and vapor temperature is the average atmospheric temperature for the season.

This method of selecting the lifter capacity seems practicable since the breathing requirements for tanks which are nearly empty probably exceed those for any other conditions.

It should be kept in mind that a lift designed to just prevent nearly all daily storage losses for any

This 5000-barrel sphere was erected to store butane at 85 pounds per square inch pressure.



particular season cannot be expected to prevent some storage losses during the transition periods from season to season.

Group C Vessels. After the first filling there can be no filling or storage losses from Group C containers, such as spheroids and spheres, if the gasoline is so volatile that its vapor pressure never falls below that at which the vacuum relief valve opens and never exceeds that at which the presure relief valve opens. As the liquid level falls and rises, evaporation and condensation, respectively, keep the pressure practically constant if the emptying and filling rates are sufficiently slow to permit the maintenance of a nearly static liquid surface temperature by the flow of heat through the tank shell to compensate for the cooling effects of evaporation and the heating effects of condensation.

However, air will be admitted to the tank if the vapor pressure is ever less than that at which the vacuum relief valve opens, and, carrying vapor with it, will be forced out when the tank is subsequently filled. In general, *assuming constant temperature during filling, and saturation of the vapor space,* the fraction of the entire tank capacity which can be filled immediately after emptying without loss is $\frac{A+\phi-\Delta}{A+\phi-p}$, in which

A = Atmospheric pressure, absolute.
ϕ = *Gauge* pressure at which the pressure relief valve opens.
Δ = The absolute pressure at which the vacuum valve opens.
p = The vapor pressure, absolute.

This ratio is derived directly from the constancy of air pressure and air volume.

$\Delta - p$ = the air pressure at the start of filling.
$\phi + A - p$ = the air pressure when the pressure-relief valve opens.
V = initial air volume = volume of vessel.
v = air volume when the pressure-relief valve opens.

$$(\Delta - p)V = (\phi + A - p)\,v$$

$$v = V\left(\frac{\Delta - p}{\phi + A - p}\right)$$

$$V - v = V - V\left(\frac{\Delta - p}{\phi + A - p}\right)$$

$$= V\left[1 - \frac{\Delta - p}{\phi + A - p}\right] = V\left(\frac{\phi + A - \Delta}{\phi + A - p}\right)$$

$$\frac{V - v}{V} = \frac{\phi + A - \Delta}{\phi + A - p} \quad \text{Q.E.D.}$$

Filling should be slow to give time for a transfer of the heat of condensation, and also of air compression, outward through the shell.

In discussing evaporation problems, it is desirable to have an expression giving the approximate number of cubic feet of saturated gasoline vapor per gallon of liquid gasoline. The expression 30 A/P, A being atmospheric pressure, and P the vapor pressure, has been much used, and may be derived as follows:

Avogadro's hypothesis may be stated thus:
The pound molecular weight of any substance existing as a gas will occupy 359 cubic feet at 32° F. and atmospheric pressure.
At 32° F. and 14.7 pounds per square inch pressure, a particular substance may not exist as a gas, but nevertheless Avogadro's hypothesis, in conjunction with Boyle's and Charles' law, may be applied to calculate the pound molecular volumes at temperatures and pressures for which the substance does exist as a gas, or as a saturated vapor.

Let:
W = Weight of one gallon of liquid, pounds
M = Molecular weight, pounds
T = Saturated vapor temperature, ° F.
p = Saturated vapor pressure at temperature T
A = Atmospheric pressure = 14.7 pounds per square inch
Z = Number of cubic feet of saturated vapor per gallon of liquid.

Then:

$359\frac{W}{M}$ = Number of cubic feet of gas at 32° F. and 14.7 pounds per square inch pressure containing 1 gallon of liquid.

$359\frac{(W)\,(T+460)}{(M)\,(32+460)} = .73\,(T+460)\frac{W}{M}$ = Number of cubic feet of gas at temperature T and 14.7 pounds per square inch pressure, containing 1 gallon of liquid, if the substance existed as a gas at this temperature and pressure.

Finally, since densities vary directly, and therefore volumes vary inversely, as the pressures:

$Z = .73\,(T+460)\frac{(W)\,(A)}{(M)\,(p)}$ = number of cubic feet of saturated vapor per gallon of liquid.

Pentane and hexane are largely responsible for the vapor pressures and liquid contents of the vapors of

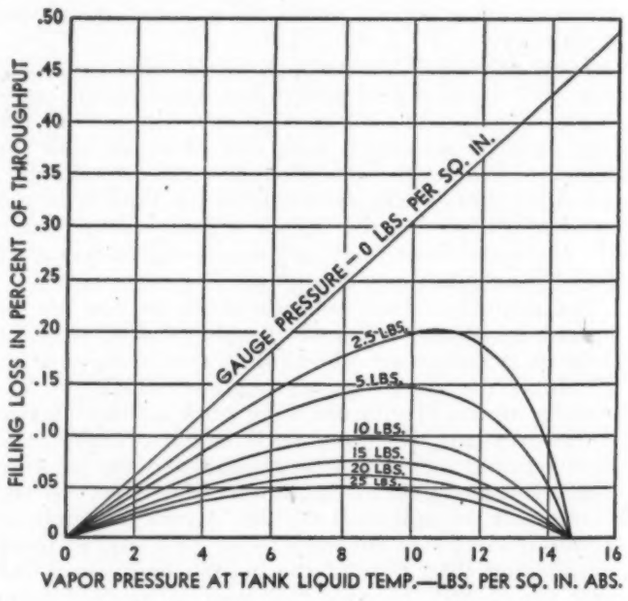


FIGURE 2

Filling losses from pressure containers.

the lighter petroleum products. For pentane $W = 5.3$ pounds and $M = 72$ pounds; for hexane $W = 5.6$ pounds and $M = 86$ pounds. Let T be taken as 80° F. Then for pentane $Z = 29\ A/p$ and for hexane $Z = 26\ A/p$. These values justify the use of $Z = 30$ to conservatively estimate the liquid content of saturated vapor space. Pentane at atmospheric pressure boils at approximately the same temperature as commercial gasoline.

Using the expression 30 A/p in conjunction with Boyle's and Charles' law, and the assumptions of a saturated vapor space and a vacuum valve opening at atmospheric pressure, it can readily be shown that

the filling loss, F, in barrels of liquid per 1000 barrels of tank capacity is given by the expression:

$$F = 4.45\left(\frac{p}{A}\right)\left(\frac{A-p}{A+\phi-p}\right).$$

V = initial air volume = $1000 \times 5.615 = 5615$ cu. ft.
v = air volume, cu. ft., when the pressure-relief valve opens = volume of vapor lost per 1000 bbl. of tank capacity.

$\frac{p}{30A}$ = approximate number of gallons of liquid lost per cu. ft. of vapor lost.

$\frac{p}{(30)(42)A} = \frac{p}{1260A}$ = approximate number of barrels of liquid lost per cu. ft. of vapor lost.

$F = \frac{pv}{1260A}$ = gallons of liquid lost per 1000 barrels of tank capacity.

ϕ = gauge pressure at which the pressure-relief valve opens.
p = the absolute vapor pressure.
A = atmospheric pressure, absolute.

From Boyle's law of the constancy of the product of pressure and volume:

$(A-p)\,V = (A+\phi-p)\,v$
$(A-p)\,5615 = (A+\phi-p)\,v$

$$v = \frac{5615\,(A-p)}{A+\phi-p}$$

$$F = \left(\frac{p}{1260\,A}\right)\left[\frac{5615\,(A-p)}{A+\phi-p}\right] =$$

$$4.45\left(\frac{p}{A}\right)\left(\frac{A-p}{A+\phi-p}\right) \quad \text{Q.E.D.}$$

It can also be shown that the vapor pressure p_m, resulting in the maximum possible filling loss for a given value of ϕ, is

$$p_m = (A+\phi)\left[1-\sqrt{1-\left(\frac{A}{A+\phi}\right)}\right].$$

The derivation follows:

From above, $F = 4.45\left(\frac{Ap-p^2}{A^2+A\phi-Ap}\right)$.

Differentiating with respect to p, equating to zero, and solving:

$(A^2+A\phi-Ap)\,(A-2p)-(Ap-p^2)\,(-A)=0$
$p^2-2p\,(A+\phi)+A\,(\phi+A)=0$

$$p_m = (A+\phi)\left[1-\sqrt{1-\left(\frac{A}{A+\phi}\right)}\right] \quad \text{Q.E.D.}$$

Figure 2 shows graphs for values of F, expressed as filling loss in percent of throughput, as ordinates, plotted against values of p in pounds per square inch as abscissae.

Curves are shown for ϕ values of 0, 2.5, 5, 10, 15, 20, and 25 pounds per square inch. The difference between the values of F for any value of ϕ and the corresponding values of F for $\phi = 0$ represent the savings due to filling against the gauge pressure ϕ as compared with filling at atmospheric pressure.

It is clear that if the vacuum valve opened at Δ pounds per square inch, absolute, instead of at atmospheric pressure the filling loss, F_Δ, in barrels of liquid per 1000 barrels of tank capacity would be

$$F_\Delta = 4.45\left(\frac{p}{A}\right)\left(\frac{\Delta-p}{A+\phi-p}\right),$$

from which it can be seen that $F_\Delta = 0$ when $\Delta = p$.

Likewise, the vapor pressure, P_Δ, resulting in the maximum possible filling loss for a given value of ϕ, is

$$P_\Delta = (A+\phi)\left[1-\sqrt{\left(1-\left(\frac{\Delta}{A+\phi}\right)\right.}\right].$$

Filling losses from Group C containers storing products with vapor pressures always or sometimes less than atmospheric pressure, may be prevented or reduced by partly filling the tank, thus utilizing the upper portion merely to hold air under pressure, or by designing and operating the tank to withstand a partial vacuum equal to the difference between atmospheric pressure and the minimum vapor pressure, as indicated by the above formula for F_Δ. Heating the tank during the coldest periods would also be effective.

During standing storage the temperature conditions in a tank are constantly changing. By night the tank usually loses heat to the atmosphere; by day it usually receives heat from the sun. There is also an exchange of heat between the tank and the earth. Radiation, convection, and conduction all take part in these temperature changes, whether the heat be incoming or outgoing.

Convection currents are most effective during the cooling periods because the upper and side layers of liquid and vapor, which first lose heat, fall to lower levels by reason of their greater density, and are replaced by warmer and lighter portions. But, during the warming periods the upper layers receive heat first, and by conduction pass some of it to the cooler layers below.

The vapor space is, therefore, practically, if not wholly, saturated at the end of a prolonged cooling period, such as one night, with nearly uniform conditions of temperature, pressure and density. But, during a warming period there is a falling temperature gradient and a rising density gradient from the roof to the liquid, and a vapor space pressure which is commonly assumed to be uniform.

Of the heat which falls on a tank some is reflected, some is absorbed by the steel, and the remainder passes into the tank, where it is expended in heating the vapor (and air, if present), heating the gasoline, evaporating gasoline, and, for volume change tanks, in enlarging the vapor space against atmospheric or higher pressure.

Evidently the radiating and reflecting properties of steel, the specific heat and thermal conductivities of steel, air, vapor and gasoline, the heat of vaporization of gasoline, the retarding effect of air on the diffusion of vapor, the effects of convection currents, and the whims of the weather, are each and all factors affecting conditions in a tank.

The general problem of pure heat conduction through a gas layer from an upper plane at one temperature to a lower plane at a lower temperature, is thoroughly treated by Leonard B. Loeb in his book on "The Kinetic Theory of Gases." This special problem is by no means simple. Much more complex is the problem of determining the true conditions in the vapor space while a storage tank is receiving heat from the sun.

It is, therefore, fortunate that a solution is not essential for design purposes. Instead of making a set of highly involved calculations of questionable accuracy to arrive at an estimate of how much of the sun's heat gets into a tank, and of how it is expended, and with what resulting temperature and pressure conditions, the designer relies upon weather records for the particular locality where the tank is to be, upon service records of similar tanks storing similar products in the same or a similar climate, and upon experimental data and good judgment as aids in deciding upon the proper storage pressure.

In the absence of specific information, he may reasonably assume that, for any particular season of the year, the liquid surface and vapor space temperature at the coldest part of each day is the average

atmospheric temperature for the season, that the maximum liquid surface temperature for any particular day in a nearly full tank is 20°F. higher than the average atmospheric temperature for the season, and that the average temperature range in the vapor space is 1¼ times the daily atmospheric temperature range. The vapor pressures corresponding to the liquid surface temperatures may be obtained from a vapor pressure versus temperature chart similar to that shown in Figure 1.

There follow the derivations of expressions for the daily evaporation loss, and for the storage gauge pressure to eliminate all standing storage loss, from Group C vessels containing products whose vapor pressures drop below atmospheric.

v = 1000 cubic feet of vapor at coldest time of the day.
V = the corresponding volume of vapor at hottest time of the day.
L = The daily evaporation loss in gallons of liquid gasoline per 1000 cubic feet of vapor space measured at the coldest time of a particular day.
p = The absolute vapor pressure at the coldest time of day.
P = The absolute vapor pressure at the hottest time of day.
t = The Fahrenheit temperature of the vapor space at the coldest time of day.
T = The average Fahrenheit temperature of the vapor space at the hottest time of day.
Δ = The absolute pressure at which the vacuum valve opens—usually a little below atmospheric.
ϕ = The gauge pressure at which the pressure relief valve opens.
A = Atmospheric pressure = 14.7 lbs. per sq. in.

$30\left[\frac{A}{\frac{1}{2}(P+p)}\right] = \frac{1000}{P+p}$, approximately, = the number of cubic feet of escaping vapor per gallon of gasoline. It is not 30 A/p because the vapor space is not saturated when the losses occur.

$\Delta - p$ = The air pressure at the coldest time of the day.

$A + \phi - P$ = The air pressure at the hottest time of the day.

Then, from Boyle's and Charles' law:

$$\frac{(\Delta - p)\,v}{t+460} = \frac{(A+\phi-P)\,V}{T+460}, \text{ whence } V = v\left(\frac{\Delta-p}{A+\phi-P}\right)\left(\frac{T+460}{t+460}\right),$$

and the loss of vapor $= V - v = v\left[\left(\frac{\Delta-p}{A+\phi-P}\right)\left(\frac{T+460}{t+460}\right)-1\right]$

$$= 1000\left[\left(\frac{\Delta-p}{A+\phi-P}\right)\left(\frac{T+460}{t+460}\right)-1\right] \text{ cu. ft.}$$

Since $\left(\frac{1000}{P+p}\right)$ cu. ft. of escaping vapor contains one gallon of liquid,

$$L = (P+p)\left[\left(\frac{\Delta-p}{A+\phi-P}\right)\left(\frac{T+460}{t+460}\right)-1\right].$$

If no losses occur,

$L = 0$, and $\phi = (\Delta - p)\left(\frac{T+460}{t+460}\right) - (A-P)$,

an expression from which the required storage gauge pressure ϕ to eliminate all standing storage losses may be estimated, using the most unfavorable average seasonal, not daily, temperature conditions of the year.

These equations show that if $\Delta = p$, and $\phi = P - A$, no losses will occur. These are the relations when no air enters the tank. They indicate the conservation value of a vacuum valve opening at as large a partial vacuum as the tank will safely withstand.

Savings Effected by Low Storage Pressures

As an illustration of the remarkable reduction in evaporation losses effected by low storage pressures, let the following reasonable data be assumed:

p = 4.5 lb. per sq. in.	P = 6 lb. per sq. in.
t = 80° F.	T = 100° F.
Δ = 14.7 lb. per sq. in.	ϕ = 1 lb. per sq. in.

Then

$$L = (4.5+6)\left[\left(\frac{14.7-4.5}{1+14.7-6}\right)\left(\frac{100+460}{80+460}\right)-1\right] = 0.95 \text{ gallons.}$$

Had ϕ been zero the loss would have been $(4.5+6)\left[\left(\frac{14.7-4.5}{14.7-6}\right)\left(\frac{100+460}{80+460}\right)-1\right]$

= 2.25 gallons, more than twice as much.

Substituting these same data in the expression $(\Delta - p)\left(\frac{T+460}{t+460}\right) - (A-P)$, the gauge pressure to prevent all standing storage losses is $(14.7-4.5)\left(\frac{100+460}{80+460}\right) - (14.7-6) = 1.9$ lb. per sq. in.

To the author the trend seems to be toward:

(a) A greater utilization of complete or partial vacuums, complementary to pressure, in reducing or preventing filling and storage losses.
(b) Increasing use of methods of storage which exclude from the storage space all air except that entrained by the entering liquid.
(c) Installing chemically inert flexible fabric hinges in Group B low-pressure devices, such as breather and balloon roofs, at connections subject to flexure where metal sheets have caused trouble by cracking.
(d) The storage in large quantities of highly volatile products such as propane. The necessary pressures, for storage at atmospheric temperatures, are too great for field-erected pressure vessels of the usual sizes and types. For example, if the maximum thickness of carbon-steel plate deemed suitable for field welding is 1¼-inch, and if the product of the design stress and joint efficiency is 11,000 pounds per square inch, and the design pressure is 220 pounds per square inch, the largest sphere which can be built for storing propane weighing 36 pounds per cubic foot is only about 20 feet in diameter.

Naturally, therefore, there is in progress an intense effort, involving both shop and field erected vessels, to discover whether pressure alone, or pressure in combination with insulation and refrigeration, is the more economical. The conclusion is not yet established.

Shell Cycling Plant Designed For High Pressure Absorption

C. C. PRYOR, Associate Editor

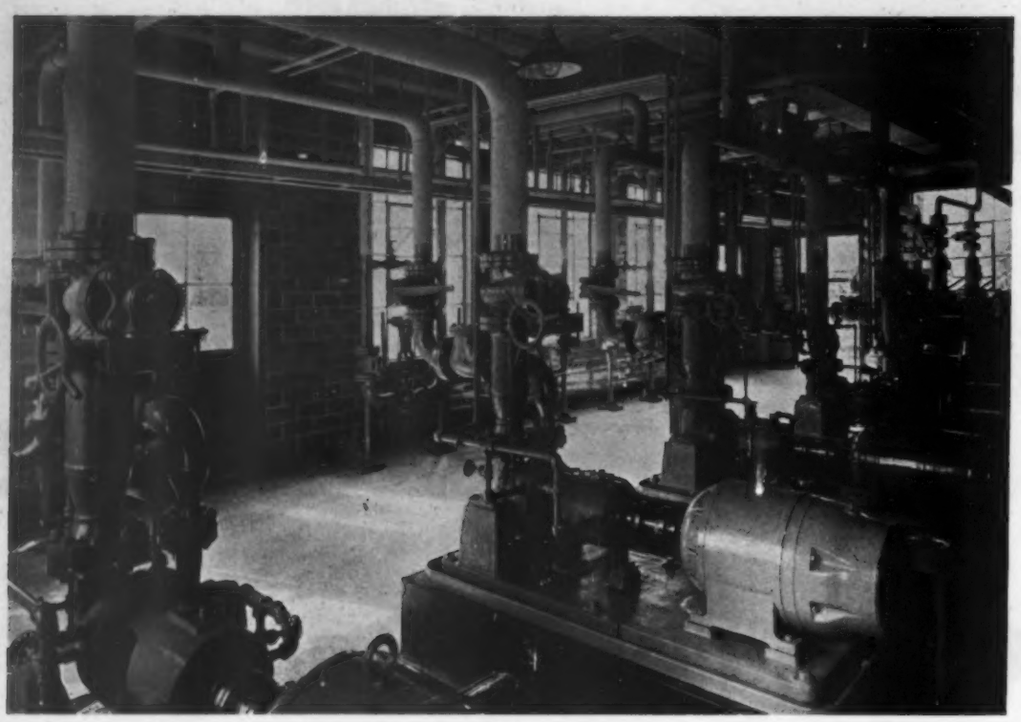
A NEW high-pressure cycling plant, designed for processing 100,000,000 cubic feet per day of gas, has been completed and placed on stream by Shell Oil Company, Inc., in the Sheridan field of Colorado County, Texas. The plant, representing the company's first venture in cycling-plant operation, will produce a total of 6700 barrels per day of products, including propane, isobutane, normal butane, isopentane, natural gasoline, and distillate. At full load, approximately 89,000,000 cubic feet per day of residue gas will be returned to the field for injection into the reservoir at a pressure of 4350 pounds per square inch, gauge.

Gas is supplied from the 9000-acre Sheridan field to the plant where it is reduced finally to 1800 psig. and fed to the main absorbers. The material balance, which governed the loads and conditions for design and selection of plant equipment is given in Table 1.

Precision fractionation of light ends provides a recovery efficiency for the plant of 85 percent minimum total butanes and 99 percent minimum total isopentane and heavier hydrocarbons. Propane is incidentally recovered, along with the butanes on which design was based. Propane, isobutane, normal butane, and isopentane are produced with a purity of 95 percent; natural gasoline—(normal pentane and heavier) isopentane contamination less than 1.5 percent liquid volume—and distillate, isopentane free, or

TABLE 1
Material Balance

Hydrocarbon	Boiling Range, °F.	Composite Charge To Plant		Total Residue Gas		Propane Product			Isobutane Product			Normal Butane Product			Isopentane Product		
		Mol./Hr.	Lb./Hr.	Mol./Hr.	Lb./Hr.	Mol./Hr.	Lb./Hr.	G.P.H.	Mol./Hr.	Lb./Hr.	G.P.D.	Mol./Hr.	Lb./Hr.	G.P.D.	Mol./Hr.	Lb./Hr.	G.P.H.
Methane	.....	9147.10	146,719	9147.10	146,719	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ethane	.....	740.00	22,252	738.18	22,197	1.82	55	17	.....	.....	.....	.....	.....	.....	.....	.....	.....
Propane	.....	424.60	18,721	298.73	13,172	125.02	5,512	1,301	0.85	37	9	.....	.....	.....	.....	.....	.....
I-Butane	.....	92.40	5,370	18.62	1,082	1.50	87	19	69.78	4,056	864	2.50	145	31	.....	.....	.....
N-Butane	.....	136.30	7,922	14.17	823	.....	.....	.....	0.94	55	11	120.59	7,009	1,440	0.60	35	7
I-Pentane	.....	50.60	3,651	0.79	57	.....	.....	.....	.....	.....	.....	0.10	7	1	47.67	3,440	660
N-Pentane	.....	49.50	3,572	0.63	46	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.60	43	8
H.-A	135—200	86.00	7,310	0.45	37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H.-B	200—250	58.20	5,820	0.10	10	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H.-C	250—420	129.10	16,912	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H.-D	420—515	35.90	6,103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H.-E	515—615	28.75	6,124	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H.-F	615—680	21.55	5,021	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	.....	11,000.00	255,497	10,218.77	184,143	128.34	5,654	1,337	71.57	4,148	884	123.19	7,161	1,472	48.87	3,518	675
Cu. Ft. per Day		100,000,000		92,897,900													
G.P.D.								32,088			21,216			35,328			16,200



Section of pump room in Shell Oil Company's Cycling Plant at Sheridan, Texas.

TABLE 2
Tower Pump Schedule

PUMP DUTY	High-Press. Lean Oil[1]	Reabsorber Lean Oil[2]	Fract. Still Refl.[3]	Rectifier Charge	Rectifier Reflux[4]	Depropaniser Reflux[5]	Debutaniser Reflux[6]	Butane Fract. Refl.[7]	Pentane Fract. Refl.[8]
Fluid	Lean Oil	Lean Oil	Gasoline	Raw Gasoline	Propane and Lighter	Propane	Natural Butane	Isobutane	Isopentane
G.P.M.—60° F	600	70	266	100	85	150	322	232	307
Specific Gravity—60° F	0.83	0.83	0.59	0.6112	170° A.P.I.	170° A.P.I.	500	0.51	0.57
Temperature °F	90	90	160	90	100	122	160	128	152
Discharge Pressure, Lb./Sq. In	1850	480	95	470	470	265	180	162	107
Suction Pressure, Lb./Sq. In	10	10	60	60	435	230	125	90	32
Diff. Pressure	1840	470	35	410	35	35	55	72	75
Total Diff. Head, Feet	5120	1310	137	....	....	....	254	326	305
Percent Efficiency	66	43	66	....	....	....	72	61	65
B. H. P	975	4.36	8.23	....	....	....	14.4	15.9	20.6
R. P. M	3550	3550	3500	....	....	....	3500	3500	3500
Size, Inches	3	1.5	3	18x8.5x18	10x8.5x18	10x10x18	3	2	2
Type	10 Stg.	....	....	High-Vol. Recipr.	High-Vol. Recipr.	High-Vol. Recipr.	....	....	....
Suction Nozzle, Inches	6	2.5	4	6	6	8	4	3	3
Discharge Nozzle, Inches	3	1.5	3	4	4	6	3	2	2
Driver	2 Steam Turbines	Electric Motor	Electric Motor	Steam	Steam	Steam	Electric Motor	Electric Motor	Electric Motor
Type	....	....	....	Recipr.	Recipr.	Recipr.	....	....	....
Voltage or Steam	200 lb.	440 V.	440 V.	200 lb.	200 lb.	200 lb.	440 V.	440 V.	440 V.
Exhaust Pressure, Lb./Sq. In	....	....	....	70 lb.	70 lb.	70 lb.	....	....	....
H. P	123—216	50	15	....	....	....	20	25	25
Steam Inlet, Inches	....	....	....	2.5	1.25	1.25	....	....	....
Steam Exhaust, Inches	....	....	....	3	1.50	1.50	....	....	....

1, 2, 3, 4, 5, 6, 7, 8 Main and Auxiliary Pumps Identical.

	n-Pentane and Natural Gasoline			Topped Distillate			Composite Products		
	Mol./Hr.	Lb./Hr.	G.P.H.	Mol./Hr.	Lb./Hr.	G.P.H.	Mol./Hr.	Lb./Hr.	G.P.H.
	.....	.....	.....	.....	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....	.....	1.82	55	17
	.....	.....	.....	.....	.....	.....	125.87	5,549	1,310
	.....	.....	.....	.....	.....	.....	73.78	4,288	914
	.....	.....	.....	.....	.....	.....	122.13	7,099	1,458
2.00	144	28	0.04	3	1	49.81	3,594	690	
47.65	3,453	656	0.42	30	6	48.87	3,526	670	
48.64	3,751	1,050	16.91	1,522	265	85.55	7,273	1,315	
20.54	2.904	514	27.56	2,906	482	58.10	5,810	996	
1.24	356	61	125.86	16,556	2,581	129.10	16,912	2,642	
	.....	.....	35.90	6,103	848	35.90	6,103	848	
	.....	.....	28.75	6,124	878	28.75	6,124	878	
	.....	.....	21.55	5,021	679	21.55	5,021	679	
82.27	12,608	2,309	256.99	38,265	5,740	781.23	71,354	12,417	
		35,416			137,760			298,008	

not more than a trace as shown by low-temperature fractional analysis.

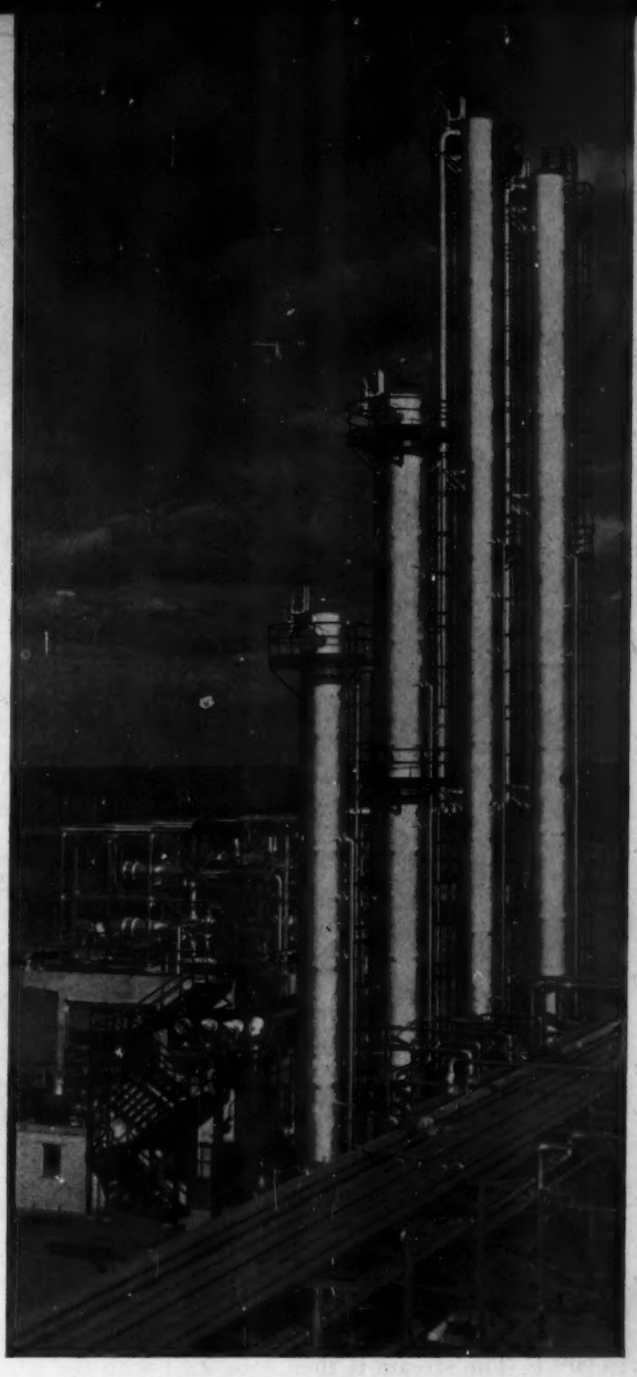
Absorption and Compression

Gas entering the plant from the field passes through two inlet scrubbers in parallel, coolers, and then through the two absorbers operated in parallel at 1800 pounds. Absorption oil, 37° API, 90° F., is pumped to each tower by a 10-stage centrifugal pump at 200-300 galons per minute. Dry overhead gas from the absorbers then passes through a residue-gas scrubber to the compressors and returned to the field for injection.

Oil used in absorption is obtained from the charge to plant, which operates with a maximum allowable loss of 800 gallons per day. The quality of the oil is controlled by the operation of the still, stripper, and purifier for a gravity of 35-40 API, molecular weight of 200-225, initial boiling point of 480-500° F., and a final boiling point of 650° F.

Seven 800-horsepower, eight-cylinder, gas-driven, angle-type compressors return gas to the field for injection at a pressure of 4350 psig. Of the seven compressors, four are used entirely for compression of residue gas for return to the field. Their capacity is supplemented by two cylinders on each of two other compressors, making a total of 20 compressor cylinders for residue gas.

One compression cylinder of the remaining compressor receives gas from the rectifier reflux tank and



Fractionating columns at Sheridan tower to 135 feet.

TABLE 3
Tower Schedule

TOWER	Size, Feet	No. Trays	Pressure Psig	Temperature °F.	Charge	Overhead	Reflux	Bottoms
Absorbers (2)	3 x 53	16	1800	100	100 MM[1] CFD	76.7-80.62[2] MM CFD	250—300[3] g.p.m.	780—860[4] g.p.m. 160-170[5]
Reabsorber	3 x 51	20	450	95	5.2-7.0 MM CFD	4.6-6.1 MM CFD	65-70[6] g.p.m.	80-85 g.p.m.
Distillate Stripper	3 x 38	15	125	425	130-140 g.p.m.	2.7 MM CFD	20 g.p.m.	82-96 g.p.m.
Fractionating Still	8 x 69.5	27	65	470	600-685[7] g.p.m. 4.2 MM[8] CFD	Vapor 134,600 Lb./Hr. Steam 6000 Lb./Hr.	240-259 g.p.m.	570-670 g.p.m.
Rectifier	3.5 x 57.5	30	450	275	3.5-5.0 MM[9] CFD 80-100 g.p.m.[10]	30,400 Lb./Hr.	78 g.p.m.	100-120 g.p.m.
Depropanizer	4.5 x 62.5	36	235	280	110-120 g.p.m.	41,044 Lb./Hr.	140-150 g.p.m.	90-105 g.p.m.
Debutanizer	6 x 72.5	40	125	305	90-105 g.p.m.	80,556 Lb./Hr.	240-250 g.p.m.	50-65 g.p.m.
Butane Fractionator	5 x 135	70	100	160	40 g.p.m.	.....	190-210 g.p.m.	25 g.p.m.
Pentane Fractionator	7 x 135	70	125	240	40-65 g.p.m.	86,282 Lb./Hr.	270-280 g.p.m.	35-40 g.p.m.

[1] Total charge to both absorbers. [2] Total dry gas from both absorbers. [3] Absorption oil. [4] Rich oil. [5] Distillate. [6] Absorption oil. [7] Liquid charge. [8] Gas charge. [9] Gas charge. [10] Liquid charge.

The two absorbers operate in parallel at 1800 pounds pressure and 100° F.

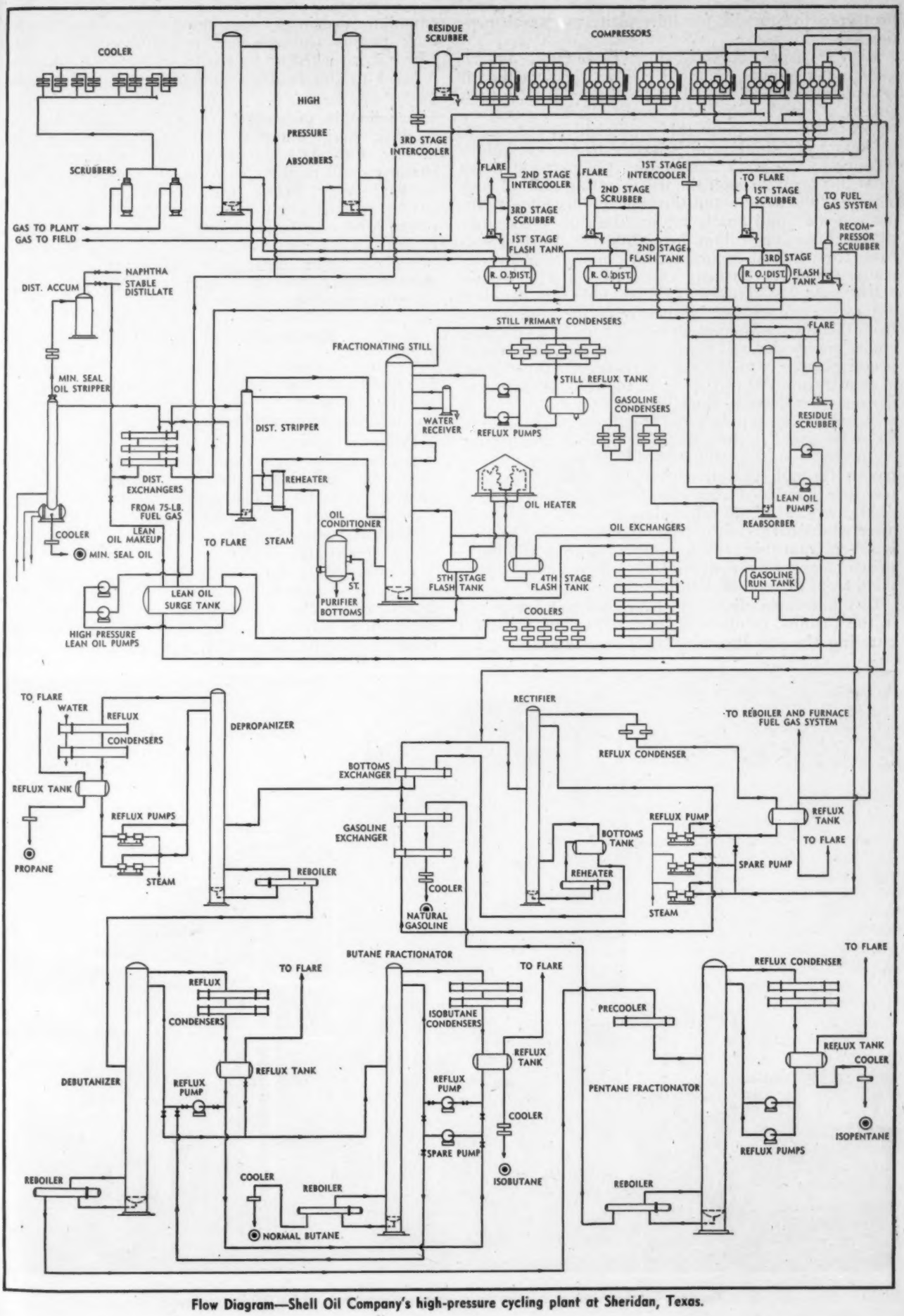
the reabsorber residue gas which is not required for plant fuel. This gas, 3,270,000 to 5,520,000 cubic feet per day of 0.825 specific gravity, is compressed and cooled in the second-stage gas intercooler from 170 to 90° F. The stream is then combined with the gas from the first-stage flash tank and passed through the third-stage booster scrubber to two other compression cylinders of the same compressor operating in parallel. After compression, the gas is cooled from 165 to 90° F. in the third-stage gas intercooler and enters the feed line to the field compressors ahead of the residue-gas scrubber.

The fourth cylinder of the compressor receives gas from the third-stage flash tank passed through the first-stage booster scrubber. This gas is cooled from 200 to 90° F. in the first-stage gas intercooler, combined with the stream from the second-stage flash tank for a total of 5,2000,000 to 7,000,000 cubic feet per day, and charged to the reabsorber below the first tray.

The two remaining cylinders on each of the last two compressors provide two-stage compression on gasoline vapors from the raw-gasoline accumulator operating at 65 psig. The two cylinders of each compressor are connected in series to achieve two-stage compression. From 3,500,000 to 5,000,000 cubic feet per day of gas are handled by these four compression cylinders. The recompressed gas is combined with raw gasoline from raw-gasoline accumulators and charged to the rectifier, where the total gasoline production, both liquid and vapor are deethanized.

Flash Staging and Distillate Stripping

Rich oil and raw distillate from the absorbers pass through three stages of flash tanks. Distillate from the third-stage Hash tank, 130-140 gallons per minute, 62° API, 75° F., passes through the distillate heat exchangers, where its temperature is increased to 265° F. heat exchange with the bottoms from the stripper column, and enters the top of the distillate stripper. The stripper overhead gas, 2,710,000 cubic feet per day, 2.18 specific gravity, is charged to the fractionating still at the top of the 19th tray. Reflux to the distillate stripper is from the bottom of the still's 19th tray at the rate of 20 gallons per minute, 270° F. The bottoms from the distillate stripper, at 425° F. and 65 pounds, is split into two streams, one flowing through the distillate exchangers to storage, and the other feeds the mineral-oil-stripper column. Overhead distillate vapor from the stripper is cooled and condensed from 400 to 100° F. after which it enters the distillate accumulator. The naphtha stream from the accumulator may be run to storage, or blended into the stable distillate, 82-96 gallons per minute, 45° API, and passed to distillate storage. Mineral-seal oil from the bottom of the stripper is



Flow Diagram—Shell Oil Company's high-pressure cycling plant at Sheridan, Texas.

pressured to storage, for lube plant use as absorption oil.

Rich oil from the third-stage flash tank, 700-780 gallons per minute, 43.8° API, flows through the oil exchangers and is heated from 95 to 325° F., then enters a fourth-stage flash tank where vapors are taken to the still. From this tank rich oil enters the oil heater at 320° F. and is heated to 470° F. before flowing to the sixth flash tank. A slipstream flows from this tank through the fractionating still oil conditioner tube bundle and through the distillate stripper reheater, and finally rejoins the full stream into the fractionating still on the eighth tray. Purifier bottoms from the oil conditioner are unsuitable for any product and are burned. Vapor from the fifth- and sixth-stage flash tanks, 4,190,000 cubic feet per day, enters the top of the eighth tray of the still. Vapor from the oil conditioner combined with still stripping steam enters the still below the first tray. Overhead gasoline vapor from the still, 134,600 pounds per hour, is cooled from 200 to 160° F. in the still primary condensers as it flows to the still reflux tank.

Reflux pump supply 240-250 gallons per minute of 80° API liquid to the still. Lean oil from the bottom of the fractionating still, 570-670 gallons per minute, passes through the oil exchangers, where the temperature is reduced from 425 to 155° F. The stream is finally cooled in the oil coolers from 155 to 90° F. after which it enters the lean-oil surge tank. Lean oil is taken from this tank for the reabsorber and high-pressure absorber towers. Lean-oil makeup is supplied from mineral-seal storage.

Gasoline vapors from the still-reflux tank are cooled in the gasoline condensers from 160 to 90° F. before entering the gasoline run tank, or raw-gasoline accumulator previously mentioned. Vapor from the run tank passes through the recompressor scrubber, where it is picked up by the recompressors and compressed to the rectifier column at 455 pounds and 220° F.

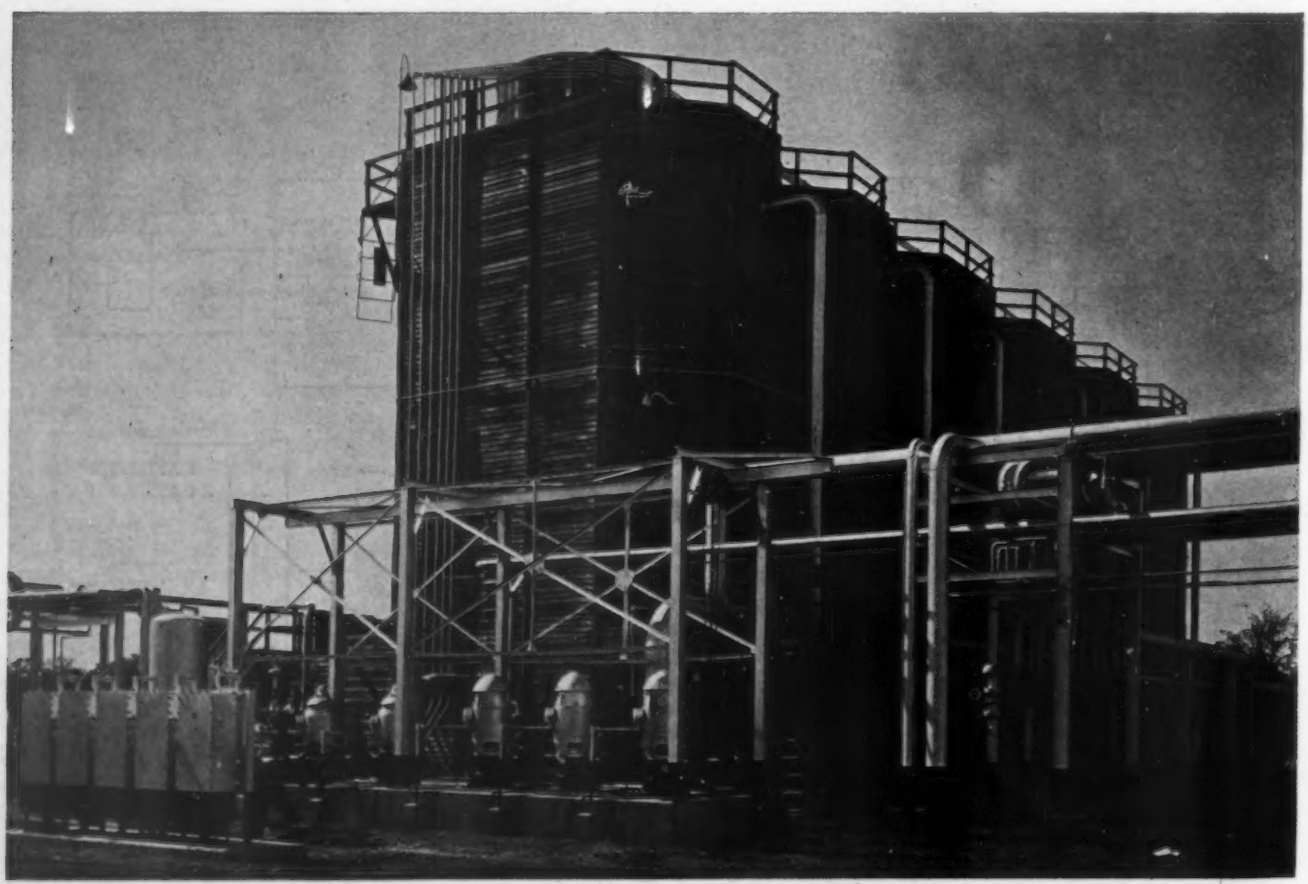
Gasoline is pumped from the run tank, by the rectifier charge pump at a rate of 80-100 gallons per minute, 100° API, passed through the gasoline exchangers and rectifier bottoms exchanger, and then to the rectifier. Reflux from the rectifier at 135° F., 304,000 pounds per hour, passes through the rectifier reflux condenser to the reflux tank. The reflux pump returns 78 gallons per minute to the rectifier. A portion of the gas from the reflux tank is compressed and the remainder enters the boiler- and furnace-fuel-gas system, previously described.

Fractionation of Light Ends

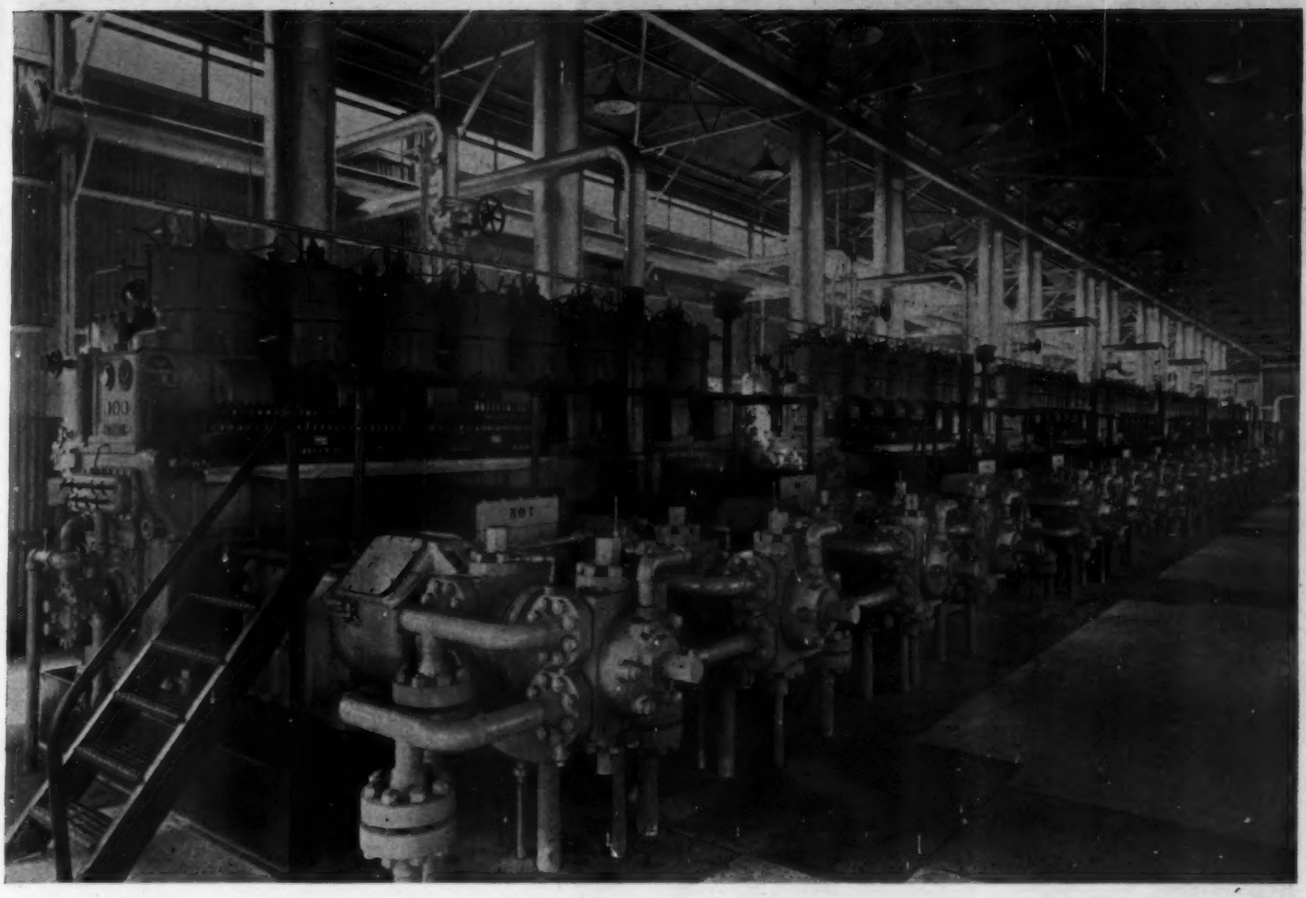
Rectifier bottoms flow through an exchanger-type reboiler to the bottoms tank. The rectifier bottoms are passed through the rectifier-bottoms exchanger and into the depropanizer at the 15th tray.

Propane vapors, 124° F., 41,044 pounds per hour, from the top of the column are cooled to 122° F. in the reflux condensers before entering the depropanizer reflux tank. The pumps return 140-150 gallons per minute of 147° API liquid propane to the column as reflux, and the remainder of the product is sent to storage.

Bottoms of the depropanizer from the reboiler, 90-105 gallons per minute, 70° API, flow to the debutanizer. The debutanized gasoline from the debutanizer reboiler is charged to the pentane fractionator on the fortieth tray. Debutanizer reflux



The six-cell cooling tower at Sheridan has a capacity of more than 121,000,000 Btu per hour.



Seven 800-horsepower, eight-cylinder, gas-driven, angle-type compressors return gas to the Sheridan field at 4350 pounds pressure.

condensers reduce the temperature of the 60,556 pounds per hour of overhead gas from 165 to 160° F. as it passes to the debutanizer reflux tank. Of the 280-290 gallons per minute picked up from the tank by the reflux pumps, 40 gallons per minute is diverted to feed the butane fractionator.

Bottoms from the butane fractionator, 25 gallons per minute of normal butane, are taken from the reboiler through a cooler, reduced from 155 to 90° F., and sent to storage. Isobutane at the rate of 190-210 gallons per minute is pumped back to the butane fractionator as reflux. From the butane reflux tank, 15 gallons per minute of isobutane flows through the coolers, 128 to 90° F., to storage.

As described previously, feed to the pentane fractionator is debutanized gasoline from the debutanizer reboiler. Bottoms from the pentane fractionator, natural gasoline or normal pentane and heavier, flow from the reboiler to the gasoline exchangers, where the temperature is reduced from 240 to 130° F., then through the final natural-gasoline cooler to storage.

Pentane fractionator overhead at a rate of 86,282 pounds per hour passes through the condensers, where it is cooled from 155 to 152° F., and finally to the reflux tank. Reflux pumps return 270-280 gallons per minute to the column and the remaining 675 gallons per hour of isopentane is passed through the cooler, reduced to 90°, and pumped to storage.

Major Equipment

The major items of equipment in the plant include the absorbers and other towers (Table 3), steam- and electric-power generation, and the cooling tower. Steam is supplied for plant operation by three 507 horsepower water tube boilers, operating at 200 psig. and supplying a total of 70,000 pounds per hour of steam. The boilers employ induced-draft fans permitting the use of 30-foot stacks, a somewhat unusual practice for plants of this type. This design provides efficient operation of the boilers at all times.

Three 800-horsepower, four-cycle, eight-cylinder, gas-powered engines driving three 695 kv-a., 555 kw., 3-phase, 60-cycle, 480-volt generators supply electric power for the plant.

The six-cell cooling tower has a capacity of more than 121,000,000 Btu per hour. Four of the six cells are employed in cooling water for distribution over atmospheric sections placed in the coil shed. Two of the cells are used to cool water for circulation through the fractionator shell and tube condensers and cooling of the engine-lubricating oil.

Product tanks, consisting of spheres and spheroids, provide a total of 31,500 barrels storage. There are two 7500-barrel tanks for distillate, two 2500-barrel tanks for natural gasoline, four 1500-barrel tanks for isopentane, and three 1000-barrel tanks for propane. Plant products are shipped by tank car from a 42-car loading rack to Shell Oil Company's Deer Park refinery (Houston) for use in making aviation and high-test motor gasoline, and industrial and domestic fuel oil.

The plant covers an area of 32 acres and was designed and built to the company's specifications by Petroleum Engineering, Inc., Houston. T. R. Goebel, manager, M. R. Church, assistant manager, and J. T. Jordan, process engineer, represented Shell Oil Company in the design and construction of the plant.

(Photographs by Elwood M. Payne)

Robert Yarnall Richie photograph courtesy Hudson Engineering Corporation

DESIGN of equipment for separation of sharp cuts of any of the lighter hydrocarbons does not vary a great deal. The described method has been proven satisfactory in a number of cases dealing with the separation of isobutane and normal butane, and isopentane and normal pentane. Special cases may require additional control equipment. The economics of a proposed installation will influence the results to be sought and, therefore, the calculations for obtaining these results. However, the fundamentals of the design for fractionators to make precise cuts are quite well established, and the methods and procedure are not particularly complicated once these fundamentals are understood.

Simplified Design for Precise Fractionation of Light Hydrocarbons

FRANK H. STONE, La Gloria Corporation

SINCE before the war there have been demands for large quantities of essentially pure hydrocarbons. Engineers and operators have had to solve problems of fractionation which theretofore had not presented themselves. It was at first considered a difficult problem to design and operate fractionators which would successfully accomplish the sharp separation of such mixtures as isobutane and normal butane. Experience has shown that this is a relatively easy job; that design and calculations are not particularly complicated and results are quite reliable.

Until the time that demands for pure components necessitated precise separations, stabilizers and fractionators were designed and built to operate with a temperature difference between top and bottom of the fractionator of 100°, 150°, or even 200° F. The design of fractionators for the separation of products with a difference in boiling points of only 21° F., as in the case of isobutane and normal butane, was viewed as a more difficult problem than design of fractionators with 100° or more difference between the top and bottom temperatures. This is not true because there is ample data available in literature to allow accurate mathematical solution of the problems involved in the separation of pure components.

A mixture of isobutane and normal butane is a typical example of the "two-component system" which has been the subject of several mathematical and graphical analyses of the principles of fractionation. The graphical method of McCabe and Thiele[1] may be applied with very good results to the problem of calculating the number of bubble trays and

the reflux ratio required for the fractionation of isobutane and normal butane. A somewhat modified form of the McCabe and Thiele method is explained by Barton[2]. This method will be illustrated by examples of its application to the design of fractionators.

Isobutane-Propane Percentages

It is necessary to know the composition of the charge stock and the expected specifications of the product. Isobutane is generally the premium product and will have to be produced to meet specifications varying from 90 to 96 percent isobutane with propane content limited to probably 2 percent. To accomplish this result, the charge stock must be purified by previous fractionation to contain less than 1 percent of propane. Since isopentane is another premium product that will remain in the debutanized gasoline or will be separated and sold as isopentane, the mixed butanes charge stock will probably contain only about 1 percent isopentane. A properly prepared charge stock may be considered as a two-component mixture since the small amounts of isopentane and propane that are present will not influence fractionation calculations or the results obtained from the McCabe and Thiele diagram. The analyses of two typical charge stocks are shown in Table 1.

TABLE 1

	Mol Percent	
	1	2
Propane	0.5	0.75
Isobutane	24.5	44.25
N Butane	73.5	54.0
Isopentane	1.5	1.0
	100	100

A desirable separation to be obtained by fractionation of each charge stock is shown:

TABLE 2

Case 1

	Mols Feed	Mols Overhead	Mols Bottoms
Propane	0.5	.5	....
Isobutane	24.5	23.0	1.5
N-Butane	73.5	.5	73.0
Isopentane	1.5	....	1.5
	100.0	24.0	76.0

Case 2

	Mols Feed	Mols Overhead	Mols Bottoms
Propane	.75	.75	....
Isobutane	44.25	43.25	1
N-Butane	54.	1.	53
Isopentane	1	....	1
	100.0	45.0	55.

In order to establish operating conditions it is necessary to know the temperature of cooling water available for condensing reflux and the temperature of steam available for supplying heat to the reboiler. It is assumed that cooling water at 90° F. and 5-pound exhaust steam at 225° F. are to be the cooling and heating mediums. With these temperatures in mind, it is well to take a look at the boiling points of isobutane and normal butane at various pressures. These may be obtained from one of several publications containing tables showing the thermodynamic properties of the two butanes. Table 3 gives the boiling points at four different pressures.

TABLE 3

	Pressure, p.s.i.g.			
	75	100	125	150
Isobutane boiling point, °F.	113	132	147	160
Normal Butane boiling point, °F.	137	155	170	183
Average boiling point, °F.	125	144	159	172
Isobutane vapor pressure at average boiling point	105	134	163	191
Normal butane vaport pressure at average boiling point	76	99	121	144
Vapor pressure ration, r.	1.38	1.36	1.35	1.33

These boiling points establish the top and bottom temperatures of a fractionator operating at the pressures shown. It is evident from the temperatures shown in Table 3 that with cooling water at 90° F. and 5-pound exhaust heating steam at 225° F., a butane fractionator might be operated successfully at any pressure between 75 and 150 pounds. At 75 pounds pressure, the column overhead temperature will be 23° F. higher than cooling water temperature, and at 150 pounds pressure the column base temperature will be 42° F. lower than the heating steam temperature.

A McCabe-Thiele diagram for butane-isobutane is shown in Figure 1. The equilibrium line is drawn by plotting calculated values (y) of the mol fraction of isobutane in the vapor corresponding to a set of assumed mol fractions (x) of isobutane in the liquid. The relationship of x and y depends upon the vapor pressure of the components, and is defined mathematically as

$$y = \frac{rx}{1 + (r-1)x}$$

in which y is the mol fraction of isobutane in the vapor, x is the mol fraction of isobutane in the liquid, and r is the numerical ratio of the vapor pressure of isobutane to the vapor pressure of normal butane at the average column temperature. The value of r does not vary a great deal over the range of anticipated operating temperatures and pressures as may be seen in Table 3.

The values of y corresponding to a series of assumed x values, calculated at 100 psig, $r = 1.36$, are as shown:

Mol Fractions

x	y	x	y	x	y
.05	.067	.40	.475	.80	.845
.10	.131	.50	.576	.90	.925
.20	.254	.60	.672	.95	.963
.30	.369	.70	.760	1.00	1.000

The equilibrium line in Figure 1 is a smooth curve drawn through points determined by plotting the above values of x vs. y on coordinate paper with abscissa and ordinate laid off in equal scales ranging from 0 to 1 by tenths. This line represents fractionation under the conditions of an infinite number of trays and minimum reflux ratio.

The 45-degree line is drawn as a straight line from point (0, 0) to point (1, 1). This line represents a condition of zero fractionation, or fractionation with a minimum number of trays and infinite reflux.

The feed line in Figure 1 is drawn vertically from a point on the x axis representing the mol fraction of overhead product in the charge stock (in this case $x = .25$; the sum of the mol fractions of isobutane and propane in the charge stock of Table 1, Case 1) to a point of intersection with the equilibrium line at A.

The operating line above the feed plate is drawn

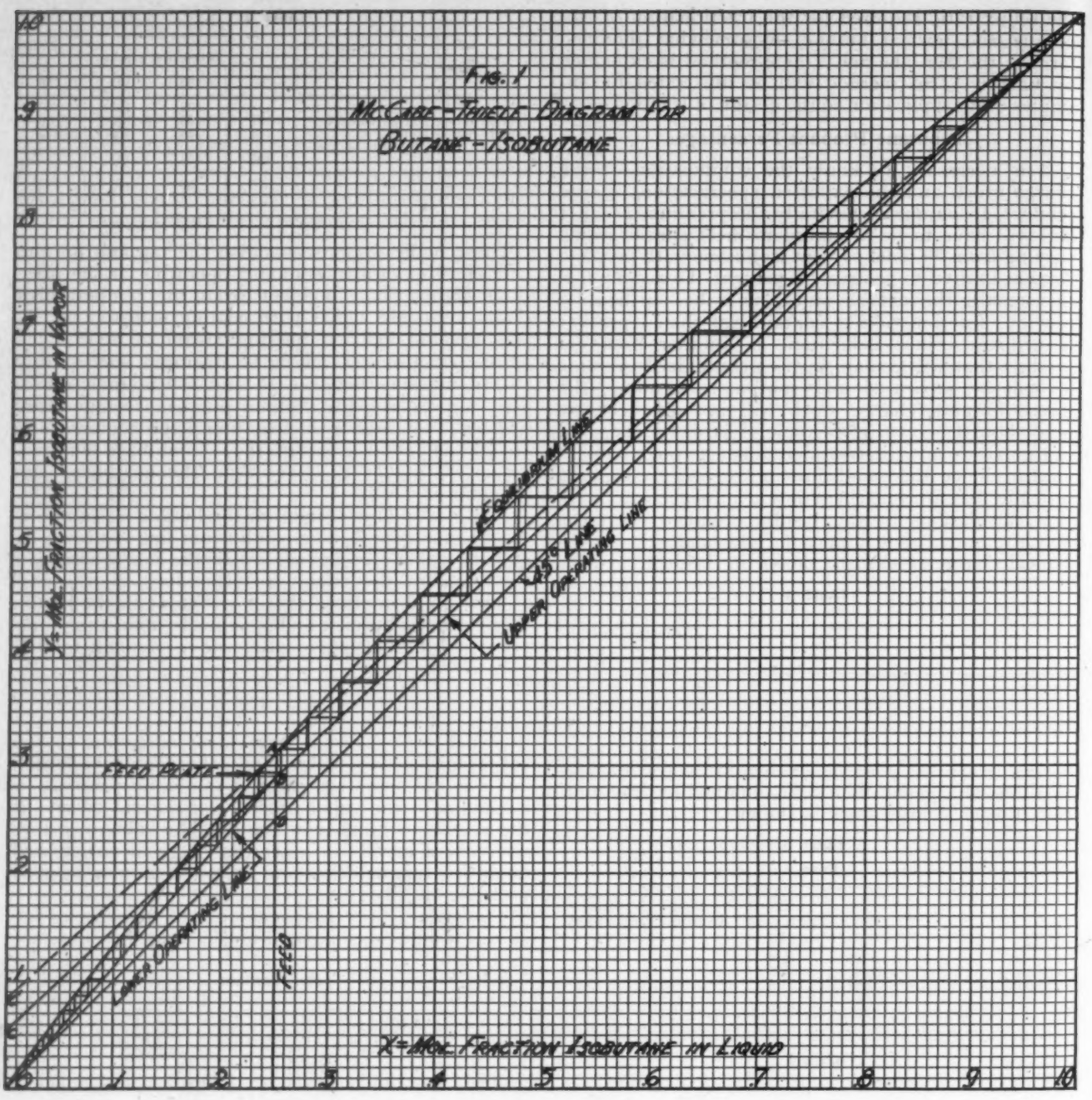


FIGURE 1
McCabe-Thiele Diagram for Butane-Isobutane.

from a point on the 45-degree line representing the concentration of the lighter component in the overhead vapor (.98) to a point B on the feed line. The operating line below the feed plate is drawn from a point on the 45-degree line representing the concentration of the lighter component in the bottom product (.02) to point B.

A continuation of the upper operating line to the y axis at point C determines a value of y that is used in calculating reflux ration, i.e., the ratio of mols of reflux to mols of overhead product. The relationship between reflux ratio, R, and the value of y at point C is

$$R = (1/y) - 1 \text{ or } y = 1/(R+1)$$

The intersection, B, of the operating lines must fall between points A and D on the feed line. The nearer B is to D, the greater the reflux ratio; while the nearer B is to A, the greater the number of plates required. The location of point B must be indicated by experience or by trial on several diagrams.

A preliminary estimate of reflux requirements may be made by drawing the upper operating line through A and then calculating minimum reflux with infinite plates from the value of y at the intersection of said line with the y axis at C′. In the example shown $y = .085$ at C′, and minimum reflux ratio $= 10.8$.

It is evident that both a large reflux ratio and a large number of plates are required. In the example a reflux ratio of 17 and a value at c of $y = .055$ was determined after a few trial diagrams were drawn.

The upper operating line is drawn from the point of .98 concentration on the 45-degree line to $y = .055$ on the y axis. The lower operating line is drawn from the point of .02 concentration to the intersection of

the upper operating line and the feed line, point B.

Starting at the intersection of the upper operating line with the 45-degree line, a continuous step-wise line alternately horizontal and vertical is drawn, crossing the space between the equilibrium and the operating lines. This step-wise line continues to the point of intersection of the lower operating line and the 45-degree line. The number of horizontal steps indicates the number of theoretical plates required for the fractionation; in this case, 37.

Number of Bubble Plates

The actual number of bubble plates required depends upon plate efficiency which is often assumed to be from 50 to 65 percent and which depends partly upon the plate design.

The fractionation of a mixture similar to the example has been accomplished with a reflux ratio of 17 in a fractionator containing 60 plates. In this case, plate efficiency was 62 percent.

A set of diagrams has been prepared based upon the charge stocks of Case 1 (25 percent overhead product in the feed), and Case 2 (45 percent of overhead product in the feed) and operating pressures of 75, 100, and 150 psig. The minimum reflux ratios as determined from these diagrams are shown in Table 4. A comparison of these ratios indicates that operating pressure has much less bearing on reflux requirements than does the composition of the fractionator feed.

TABLE 4

	Percent Overhead Product in Feed					
	25			45		
Pressure, p.s.i.g.	75	100	150	75	100	150
Min. Reflux Ratio	10.1	10.8	11.8	5.5	5.8	6.4

The completion of several of these diagrams to determine the theoretical plate requirements gave the results shown in Table 5.

TABLE 5

	Percent Overhead Product in Feed				
	25		45		
Pressure, p.s.i.g.	100		100		150
Reflux Ratio	10	17	10	17	10
Theoretical Plates	Inf.	37	40	32	44
Estimated Actual Plates	Inf.	60	65	52	71*

* A 70-plate fractionator is performing a similar fractionation.

The diameter of the fractionator may be calculated by means of an entrainment formula which will indicate the vapor velocity at which liquid will carry from plate to plate up the fractionator. Entrainment is governed by vapor velocity, plate spacing, plate and downcomer design, liquid seal on plates, and physical properties of vapor and liquid. Several entrainment formulae suitable for estimating allowable vapor velocity have been published. The formula that appears in *Chemical Engineer's Manual*[3] is shown:

$$U = K\sqrt{\frac{d_1 - d_2}{d_2}}$$

where U = allowable vapor velocity, ft./sec. based on cross-sectional area of fractionator
d_1 = density of liquid downflow at column temperature
d_2 = density of vapor at column conditions
K = a constant

The approximate value of K depends upon plate spacing and amount of liquid seal on plates. A table in *Chemical Engineer's Manual* assigns a value to K of .09 for the conditions of 18-inch plate spacing and a liquid seal of 3 inches.

Vapor Flow

It is safe to assume that the volume of vapor flowing up the fractionator is about the same throughout, and determine fractionator diameter from the vapor velocity at the top. In this case, both liquid and vapor are essentially pure isobutane and at 100 psig pressure

d_1 = 31.92 lb./cu. ft. of liquid at 132° F.
d_2 = 1.27 lb./cu. ft. of vapor at column conditions

$$U = .09\sqrt{\frac{31.92 - 1.27}{1.27}} = .44 \text{ ft./sec.}$$

In the operation of a butane-isobutane fractionator at 100-pound pressure and with 18-inch plate spacing, a maximum allowable vapor velocity of .53 foot per second was determined by test. This indicates that the entrainment formula as applied above is on the conservative side by about 20 percent.

It is evident from the foregoing that since the volume of reflux required for the fractionation of the butanes so far exceeds the volume of fractionator feed or products, this reflux volume is the determining factor in arriving at fractionator diameter.

Likewise, reflux volume is the largest single factor in determining heat loads, and therefore the size of overhead condensers, cooling tower and cooling water requirements; the size of the reboiler, and quantity of heating steam required; and the size of reflux and circulating water pumps.

Therefore, it is generally economical to install a fractionator containing the largest number of plates that is considered practical. For separating the butanes, fractionators containing 60 to 70 plates and having a shell length of 100 to 130 feet are no longer uncommon.

Equipment Required

Shown in Figure 2 is a flow diagram of an isobutane-normal butane fractionator installation. This diagram includes what is probably the minimum amount of equipment required for good operation, but it is representative of several actual installations.

The feed may be drawn directly from a regulator on the preceding fractionator unless the plant is subject to considerable variation in volume and composition of throughput, in which case it would be advisable to install a feed surge tank and draw from it, by pressure or pumping, through a regulator operated by a flow controller. The location of the feed nozzle may be determined from the McCabe-Thiele diagram by counting the theoretical trays above and below the intersection with the feed line. It is good practice to have at least three feed nozzles located four plates apart in the vicinity of the determined plate. The quantity of internal reflux so outweighs the quantity of feed that it makes little difference whether or not the feed is preheated.

Reflux is returned to the fractionator at a constant rate through a regulator operated by a flow controller which is reset manually as required.

The total overhead vapor stream from the fractionator passes through the reflux condenser and is totally condensed in the reflux accumulator. The isobutane overhead product is drawn off through a cooler by means of a regulator operated by a pressure controller. The reflux accumulator stands full of

isobutane, and isobutane liquid backs up into the condenser. Any increase in fractionator pressure causes the regulator to open and draw off more product, thus uncovering more condensing surface and thereby lowering the fractionator pressure. A drop in fractionator pressure results in the reverse satisfactory. The temperature controller remains connected to the same control point but is allowed to operate the isobutane draw-off regulator. A rise in temperature tends to close the draw-off valve, and a drop in temperature tends to open it. At constant pressure, the temperature of the mixture at the con-

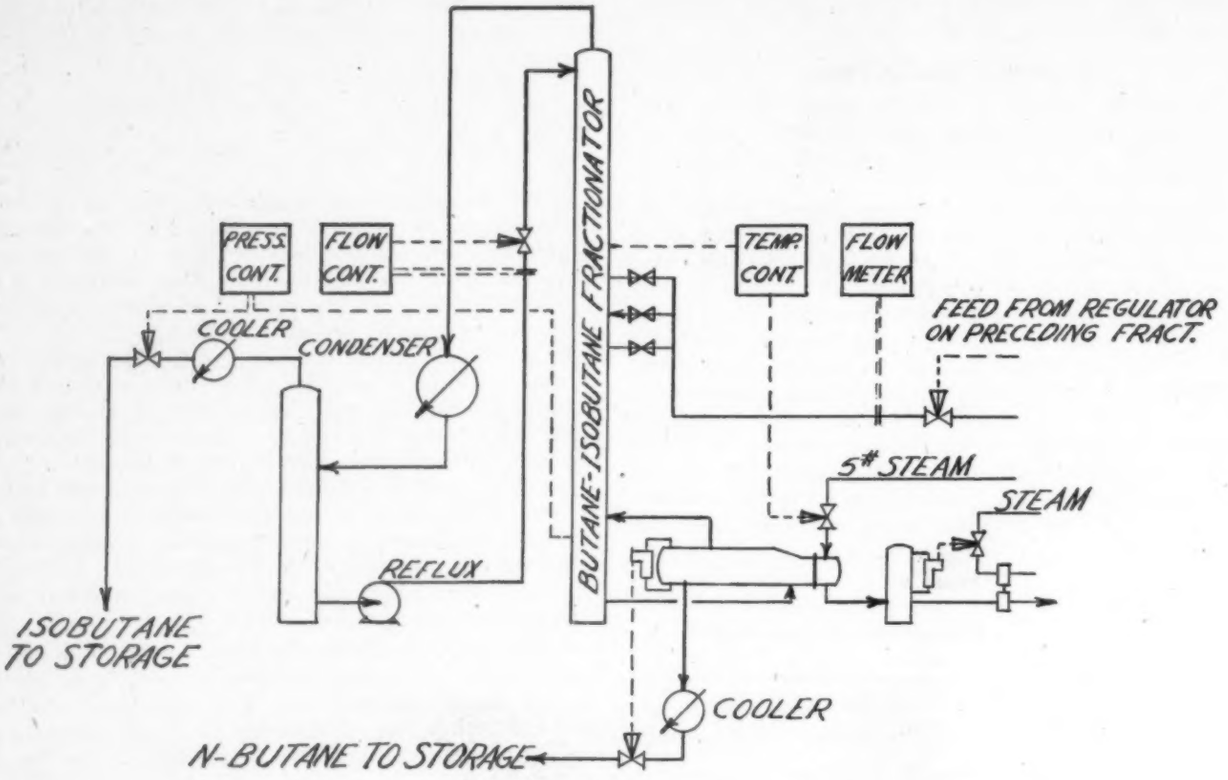


FIGURE 2
Flow Diagram: Butane-Isobutane Fractionator.

of the above action. In order to promptly remove any uncondensed light hydrocarbons that might enter the fractionator as a result of an upset in the operation of other plant equipment, it is advisable to have the isobutane draw-off connection at the top of the reflux accumulator. The condenser and cooler may be of either the tube-and-shell or open atmospheric types of equipment.

The normal butane is drawn off through a cooler by means of a regulator operated by a level controller on the reboiler.

Fractionator temperature is controlled by a temperature controller operating a regulator that admits steam to the reboiler. The temperature control point is located halfway up the column, or higher, in order to have it on a plate that carries about a 50-50 mixture with the widest possible boiling range. Pressure on the steam side of the reboiler will be near or below atmospheric pressure; therefore, a small tank is required to collect condensed steam to allow it to be removed by a pump which is governed by a level controller on the tank.

The temperature and pressure instruments may be connected in an alternate arrangement which, though not in common use, has been proven to be very trol point is a direct function of the composition of that mixture. A rise in temperature indicates that the normal butane content of the mixture has suffered an undesirable increase. The controller then decreases the volume of isobutane being removed as product and, since reflux volume is constant, automatically increases the ratio of reflux to product until the mixture at the control point is restored to normal.

Constant pressure is obtained by allowing the pressure controller to operate the regulator that feeds steam to the reboiler. Any variation in the heat demand of the fractionator, or in the quantity or quality of the steam entering the reboiler, will result in a change in the rate of vaporization of the normal butane in the reboiler. This change in the rate of vaporization immediately tends to change the pressure at the base of the fractionator. The pressure controller will then adjust the regulator supplying steam to the reboiler until the rate of vaporization of the reboiler liquid restores normal operating pressure.

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[1] McCabe and Thiele, Ind. Eng. Chem., 17, 1925, p. 605.
[2] The Science of Petroleum, Vol. II, Oxford University Press, New York.
[3] Chemical Engineer's Manual, Keyes and Deem, John Wiley & Sons, New York.

A Rapid Test for Isobutane (+) Fractions in Natural Gasoline Plant Absorber Residue Gases

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PRESENTED is a field testing method for determining losses of isobutane (+) fractions in absorber plant residue gases. Advantage of the method is that a test may be completed and results computed in about two hours, and indicated changes in plant operations may be made and results again checked by a repeat test.

The paper is a revision of a presentation before the Fall Meeting (1944) of California Natural Gasoline Association, the authors having completed further work and revision of the standardization chart.

DURING the past few years isobutane and normal butane were critical war materials, and as a result natural-gasoline absorption plant operations were stepped up for maximum extraction of these fractions. This condition created the need for a rapid field-testing method for determining the losses of isobutane (+) fractions in plant residue gases. The conventional fractional analysis method was unsatisfactory because very large samples had to be analyzed to obtain acurate cuts when the key fractions were present in low concentrations. Consequently, time requirements were excessive and there was too much delay in obtaining results.

The need for a quick test was met by developing a method along the lines of the Butanes Absorption-Weathering Test (B-W Test) for pentanes (+), which was presented at the February, 1935, meeting of the California Natural Gasoline Association by R. N. Donaldson of Standard Oil Company of California. This earlier pentanes (+) test consists of passing a metered volume of gas through a liquid butane solvent at —44° F. temperature and weathering the contacted solvent to a prescribed endpoint temperature. The new isobutane (+) test is similar except that it is run at —110° F. and employs a liquid propane solvent. This similarity permits combining the two methods, and both have been incorporated in the attached procedure, thus providing a means for determining the butanes and the pentanes (+) contents of absorber residue gases. The butanes may be split into iso and normal butane when absorption factor and intake composition data are known.

Figure 1 shows a drawing of the combination tube which is employed in both the absorption and

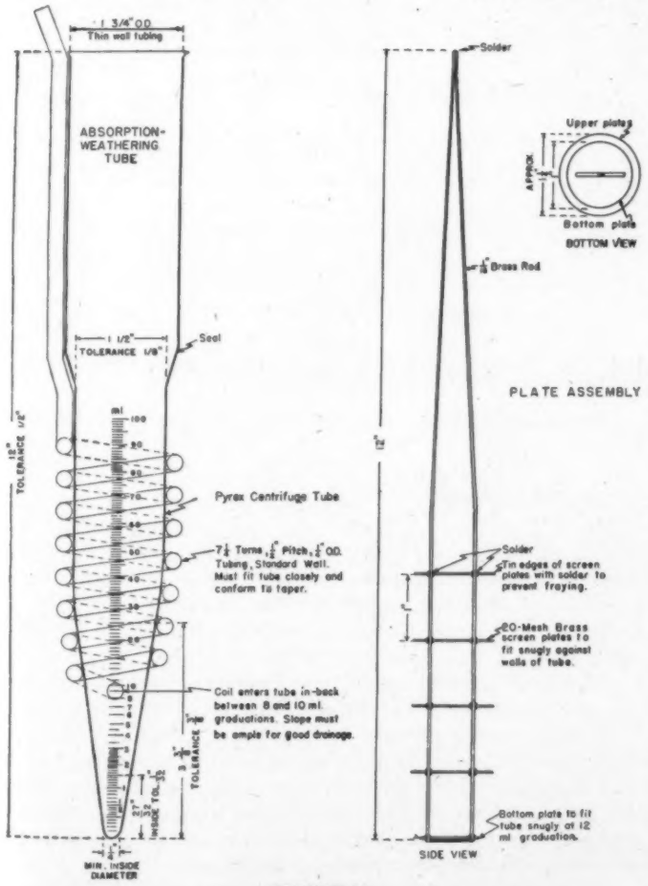

1 3/4" OD
Thin wall tubing
ABSORPTION-WEATHERING TUBE
1 1/2" TOLERANCE 1/8"
Seal
Pyrex Centrifuge Tube
Coil enters tube in-back between 8 and 10 ml. graduations. Slope must be ample for good drainage.
MIN. INSIDE DIAMETER
Solder
Upper plate
Bottom plate
BOTTOM VIEW
Brass Rod
PLATE ASSEMBLY
Solder
Tin edges of screen plates with solder to prevent fraying.
80-Mesh Brass screen plates to fit snugly against walls of tube.
Bottom plate to fit tube snugly at 12 ml graduation.
SIDE VIEW

FIGURE 1
Details of absorption-weathering tube and plates.

C.N.G.A. Liquefied Petroleum Gas Thermometer Specifications (TS-441)

NAME	C.N.G.A. High L.P.G. Test	C.N.G.A. Low L.P.G. Test
Liquid	Mercury	Toluene
Type	Etched stem, glass, plain front	Etched stem, glass, plain front
Temperature Range	0° to plus 45° F.	0° to minus 70° F.
Subdivisions	⅕° F.	½° F.
Total Length	15" ± 1"	13" ± 1"
Stem Diameter	5 to 8 mm.	5 to 7 mm.
Bulb Diameter	5 to 6 mm.	6 mm ± 0.5 mm.
Bulb Length	17 to 21 mm.	20 to 25 mm.
Length of Scale	11" ± 1"	5½" ± ½"
Top Finish	Glass Ring	Glass Ring
Longer Graduations at Each	1° F.	1° F.
Graduations Numbered at each multiple of	2° F.	5° F.
Immersion	1½"	4½"
Scale error at any point when standardized shall not exceed	⅒° F.	¼° F.
Expansion Chamber	Shall permit heating to 140° F. and be at least 1" above the top graduation on scale.	

FIGURE 2

weathering steps. The tube is filled to the 100 ml. mark with the appropriate solvent and immersed in an L.P.G. cooling bath. The test is conducted at a low temperature to minimize the loss of butanes or pentanes (+) fractions during the absorption step and to prevent excessive loss of solvent. The meter and auxiliary equipment are connected as shown in Figure 3. The gas to be tested is passed through the solvent until the desired amount of material is absorbed. The contacted solvent is then allowed to weather in the air until the liquid residue reaches

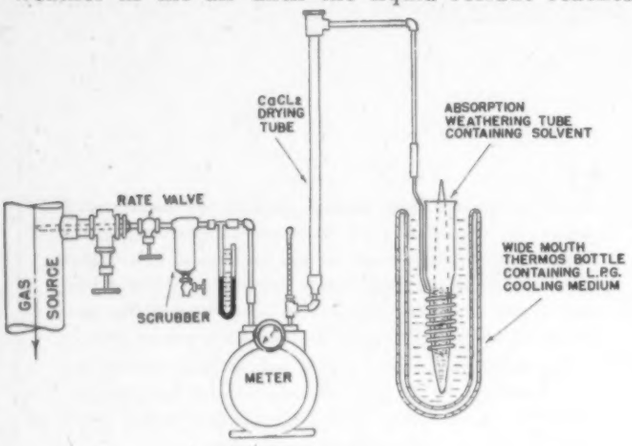


FIGURE 3
Arrangement of apparatus.

the prescribed endpoint temperature. Boiling is then stopped by momentarily immersing the tip of the tube in the cooling bath, and the residue volume is read and recorded. The residue volume is then converted to ml. of isobutane(+) or pentanes(+) by the standardization charts given below.

Specifications for the two solvents, which are given in the attached procedure, show that the B-W Test employs an absorbent consisting of a pentanes-free mixture of isobutane and normal butane containing a maximum of 10 percent of propane. The quality of this solvent changes somewhat during the absorption step, and an intermediate weathering temperature (10 ml. vol.) is required for proper interpretation of the residue results. The P-W Test solvent consists of a butane-free propane cut containing a maximum of 5 percent ethane.

Relation Between Barometric Pressure (or Elevation) and 10 ML. Temperature Correction and Endpoint Temperatures

ELEVATION, FEET	Barometric Pressure mm. of Hg.	Correction to Observed 10 ml. Weathering Temperature °F.	B-W Tets Endpoint Temperature °F.	P-W Test Endpoint Temperature °F.
—450 to —276 (Below Sea Level)	770	Deduct 0.6	+35.6	—36.4
—275 to —101 (Below Sea Level)	765	Deduct 0.3	+35.3	—36.7
—100 to +100 (Above Sea Level)	760	0.0	+35.0	—37.0
100 to 275	755	Add 0.3	+34.7	—37.3
276 to 450	750	Add 0.6	+34.4	—37.6
451 to 650	745	Add 0.9	+34.1	—37.9
651 to 850	740	Add 1.2	+33.8	—38.2
851 to 1025	735	Add 1.5	+33.5	—38.5
1026 to 1200	730	Add 1.8	+33.2	—38.8
1201 to 1400	725	Add 2.1	+32.9	—39.1
1401 to 1600	720	Add 2.4	+32.6	—39.4
1601 to 1800	715	Add 2.7	+32.3	—39.7
1801 to 2000	710	Add 3.0	+32.0	—40.0
2001 to 2200	705	Add 3.3	+31.7	—40.3
2201 to 2500	700	Add 3.6	+31.4	—40.6
2500 to 2900	690	Add 4.2	+30.8	—41.2
2901 to 3300	680	Add 4.8	+30.2	—41.8
3301 to 3700	670	Add 5.4	+29.6	—42.4
3701 to 4100	660	Add 6.0	+29.0	—43.0
4101 to 4450	650	Add 6.6	+28.4	—43.6
4451 to 4850	640	Add 7.2	+27.8	—44.2
4851 to 5250	630	Add 7.8	+27.2	—44.8
5251 to 5650	620	Add 8.4	+26.6	—45.4
5651 to 6050	610	Add 9.0	+26.0	—46.0

FIGURE 4

Standardization Curves

Standardization charts, Figures 6 and 7, convert the B-W Test residue volume to actual ml. of pentanes(+). The curves shown in Figure 6 were obtained by adding known amounts of normal pentane to a butanes solvent and weathering the mixture to the endpoint temperature of 35° F. Residue volumes and observed 10 ml. temperatures were then plotted against the ml. of normal pentane added to the solvent. This curve sheet is applicable when the quality of the pentanes(+) is equivalent to normal

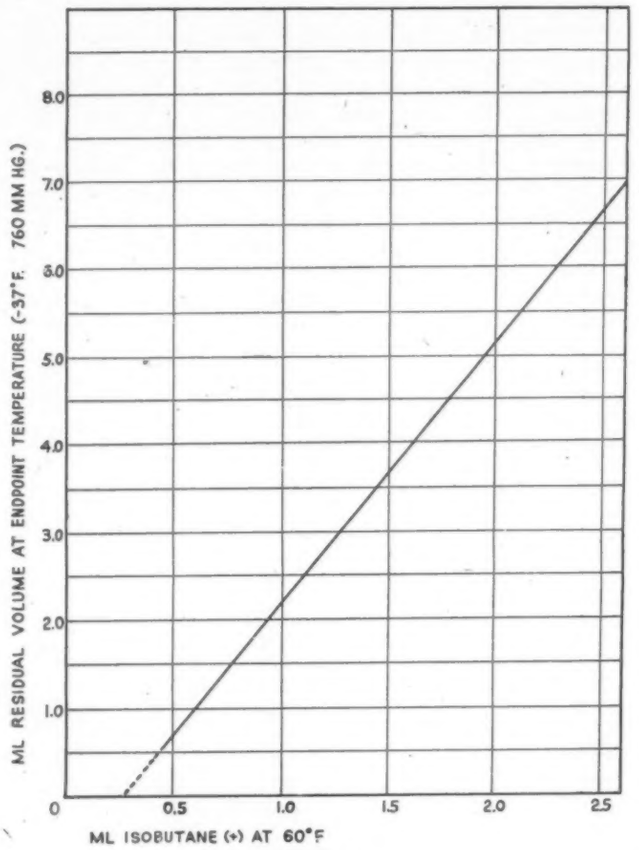


FIGURE 5
P.W. Test Standardization Curve for absorber residue isobutane(+) in propane solvent.

$$\text{Isobutane(+) (gal/mcf)} = 0.264\left(1 + \frac{\text{cor. cu. ft.}}{100}\right)\frac{\text{ml. isobutane(+)}}{\text{cor. cu. ft.}}$$

pentane. When the quality is not equivalent to normal pentane, Figure 7 is used to convert the ml. of normal pentane to actual ml. of pentanes(+). A factor of 0.5 is normally used for the losses due to the vapor pressure of the lean oil, and a 1.0 factor for the losses due to incomplete absorption. The absorption loss can be neglected when the absorption factor with respect to isopentane is 2.0 or higher.

Figure 5 converts the P-W Test residue volume to ml. of isobutane(+). This chart was developed by adding known amounts of isobutane, normal butane, and pentanes(+) to a propane solvent and weathering the mixture to an endpoint temperature of —37° F. It was found that variations in the isobutane-normal butane ratio had little effect on results in the presence of the pentanes(+) fractions.

After converting the test residues to ml. of isobutane(+) or pentanes(+) by use of the standard-

Comparison with Fractional Analysis

Absorber Residue Gas	SAMPE 1		SAMPLE 2		SAMPLE 3		SAMPLE 4		SAMPLE 5	
	Fract.* G/M	PW-BW G/M	Fract.* G/M	PW-BW G/M	Fract.* G/M	PW-BW G/M	Fract.* G/M	PW-BW G/M	Fract.* G/M	PW-BW G/M
Isobutane	0.067	0.061	0.116	0.085	0.028	0.024	0.060	0.062	0.055	0.050
N-Butane	0.031	0.028	0.055	0.096	0.004	0.006	0.050	0.058	0.019	0.026
Pentanes(+)	0.006	0.006	0.007	0.007	0.009	0.008	0.015	0.011	0.016	0.016
Isobutane(+)	0.104	0.095	0.178	0.188	0.041	0.038	0.125	0.131	0.090	0.092
	*6.5 cu. ft. analyzed		*3.8 cu. ft. anaylzed		*10.0 cu. ft. analyzed		*10.0 cu. ft. analyzed		*4.0 cu. ft. analyzed	

FIGURE A

ization curves, the gallons per thousand cubic feet enrichments are computed according to the usual formula.

Accuracy

In developing this testing method, it was concluded that determinations of absorber losses within ± 10 percent would be satisfactory. To accomplish this is difficult because 10 percent accuracy on a 0.10 gallon per thousand cubic feet residue gas requires accuracy to within 0.01 gallon per thousand, which corresponds to about 0.03 percent with respect to the total gas sample. Judging from the comparison with 30- to 40-hour analyses on several absorber residue gases, Figure A, this objective have been met reasonably well for the average range of conditions. Discrepancies are expected when materials present in the gas deviate widely from conditions of standardization. When this source of error is serious, it is not difficult to prepare special calibration curves. One advantageous feature of the test is that workable quantities of liquid isobutane(+) or pentanes(+) may be accumulated by passing a sufficient volume of gas through the absorption tube.

Application

The chief advantage of the test rests in the ability to obtain an answer at the plant in a relatively short time. A test may be completed and results computed in about two hours' time. If necessary, plant operations may be changed immediately and improvements checked by a repeat test.

It is especially adapted to obtaining an absorption factor test relationship such as shown in Figure B. The absorption factor—residue loss curves so obtained provide a valuable tool for evaluating absorber losses over a range of operating conditions. Also, in conjunction with intake analyses, they provide a satisfactory means of comparing absorber efficiencies.

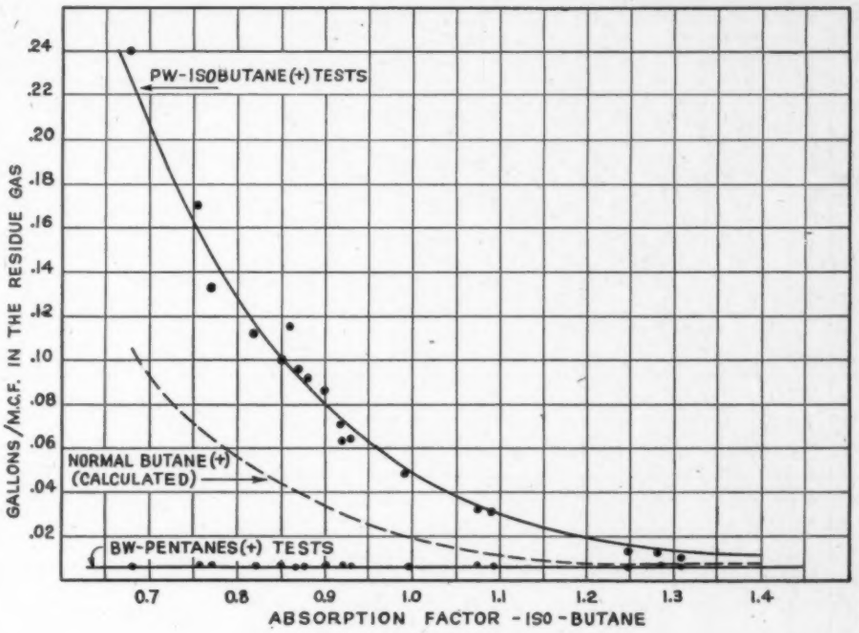


FIGURE B

Residue losses vs. absorption factor.

Determination of the Isobutane (+) and Pentanes (+) Contents Of Absorber Residue Gases

Scope

This procedure presents methods for determining the isobutane(+) content (P-W Test) and/or the pentanes(+) content (B-W Test) of natural gasoline plant absorber residue gases. The two tests are similar except that the isobutane(+) material is absorbed in a propane solvent at —110° F., whereas pentanes(+) material is absorbed in a butane solvent at —44° F.

Apparatus

Absorption-Weathering Tube, Screen Plates, conforming to the specifications shown in Figure 1.

Thermometers:

P-W Test, conforming to the specifications for the C.N.G.A. *Low* L.P.G. test thermometer given in Figure 2.

B-W Test, conforming to the specifications for the C.N.G.A. *High* L.P.G. test thermometer given in Figure 2.

Displacement Meter, of known calibration, capable of measuring the gas volume to 0.01 cubic feet or less; preferably reserved for tests on lean gases to avoid condensate errors.

Drying Tube, consisting of a tube ¾-inch in diameter by 2 feet long, or its equivalent, containing 8-mesh anhydrous technical grade calcium chloride.

Solvents, conforming with the following specifications:

	P-W Solvent	*B-W Solvent*
Ethane	5% max.	—
Propane	95% min.	10% max.
Isobutane	None	*Balance*
N-butane	None	30-40%
Pentanes(+)	None	None

These solvents must be made from paraffinic liquefied petroleum gas stocks, such as produced in natural gasoline plants.

Cooling Coil: The cooling coil shall consist of 4 feet of ¼-inch O.D. seamless copper tubing formed into a spiral by winding on a short length of ¾-inch pipe, allowing sufficient length of tubing to connect the bottom of the spiral to the liquefied-gas sampling connection. The outlet extension of the coil shall be fitted with a needle valve; and a short piece of flexible tubing shall be attached to the valve outlet for insertion into the neck of the weathering tube, or solvent storage bottle.

Low-Temperature Cooling Baths: A low-temperature cooling

bath contained in a one-quart, wide-mouth thermos bottle is required in each test. The bottle shall be filled with a CO_2 snow-commercial propane mixture (Bath A) for the P-W Test, and with commercial propane only (Bath B) for the B-W Test. To avoid foaming, the CO_2 snow-propane bath shall be prepared by filling the thermos bottle first with CO_2 snow and then with propane, after which additional CO_2 snow may be added.

Water Bath (B-W Test only): The water bath shall be at least 4 inches in depth and of sufficient volumetric capacity that it will maintain a temperature of 60-70° F. throughout a test, by a single temperature adjustment before starting. A

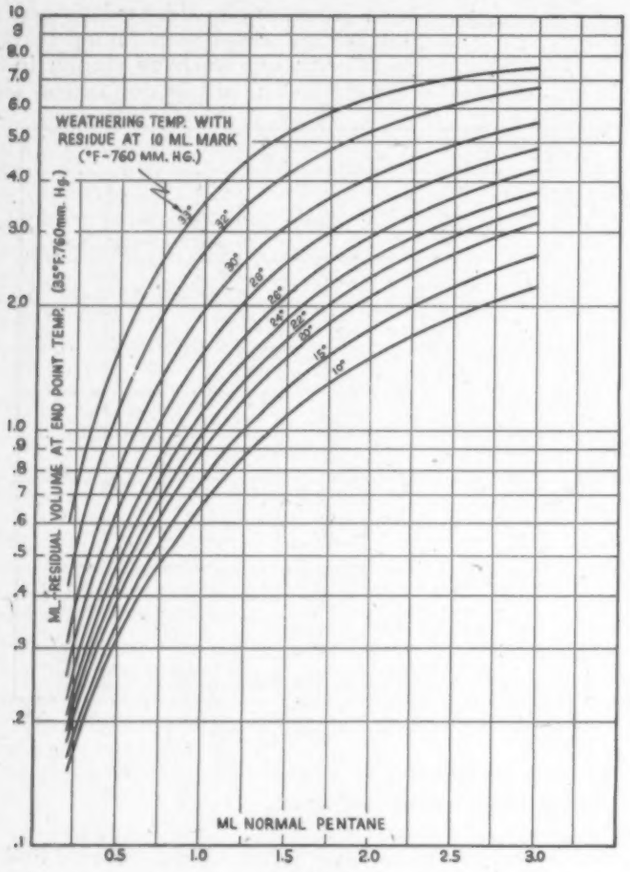


FIGURE 6
B.W. Test Standardization Curves (for normal pentane).

glass battery jar approximately 6 inches O.D. and 12 inches high, is recommended.

Ice Bath (B-W Test only): A thermos bottle filled with finely crushed ice in distilled water shall be provided to check the accuracy of the test thermometer.

Tube Support: Means shall be provided to support the absorption tube in a vertical position during the weathering step.

Field Kit: In addition to apparatus specified above, a kit for field tests shall include extra one-quart pyrex thermos bottles for the storage of solvents and refrigerants, pinch clamps, and sufficient copper and rubber tubing for connections. The complete kit for both P-W and B-W Tests will then include the following items:

2 Absorption-weathering tubes with screen plates.
2 One-quart, small-mouth thermos bottles holding solvent.
1 One-quart, small-mouth thermos bottle holding commercial propane.
1 One-quart, wide-mouth thermos bottle holding CO_2-snow.
2 One-quart, wide-mouth thermos bottles (Bath A and Bath B).
1 Thermos bottle, ice bath.
1 Meter.
1 $CaCl_2$ drying tube.
2 Pinch clamps.
1 Weathering tube support.
2 C.N.G.A. LPG test thermometers (1-*High* Test, 1-*Low* Test).
Sufficient copper and rubber tubing for connections.

Preparations

Check Thermometers: The C.N.G.A. *High* L.P.G. test thermometer shall be inserted in the ice bath and checked for accuracy. If the thermometer fails to read 32° F.± 0.1° F., an attempt should be made to adjust it to that condition, by warming to above 45° F. and/or cooling below 10° F., tapping gently to cause separated globules of mercury to join the main column. If the thermometer is in error with the mercury column intact, it should not be used.

The C.N.G.A. *Low* L.P.G. test toluene thermometer shall be inspected before each test to see that the liquid is not separated and that there is no red discoloration above the toluene. Any red discoloration in the expansion bulb at the top shall be removed by immersing the bottom of the thermometer in a propane bath while applying a cloth wet with hot water to the expansion bulb. If the thermometer accuracy is in doubt, it shall be checked at 0° F. against the C.N.G.A. *High* L.P.G. test thermometer in a well-stirred bath with both thermometers immersed to their respective immersion marks.

Thermometer inaccuracies can be kept at a minimum by handling and storing the thermometers in a vertical position in appropriate cooling baths.

Clean Weathering Tube: The weathering tube shall be thoroughly cleaned and dried. It is essential that the tube be free from any heavy hydrocarbons.

Prepare Water Bath (B-W Test only): Fill the water bath to a depth of at least 4 inches and adjust the temperature to approximately 65° F.

Prepare Cooling Baths: Prepare low-temperature cooling baths (A) and/or (B).

Precool Thermometers: Precool the *High* test thermometer in the ice bath, and the *Low* test thermometer in Bath (B) for at least 30 minutes before test use.

Draw Solvent: Invert solvent cylinder, attach cooling coil to cylinder valve, and with coil immersed in appropriate low-temperature cooling bath (A for P-W, B for B-W test), draw the required solvent into a one-quart, small-mouth pyrex thermos bottle. Solvent withdrawal shall be controlled by the valve on the coil outlet in order to keep full pressure on the

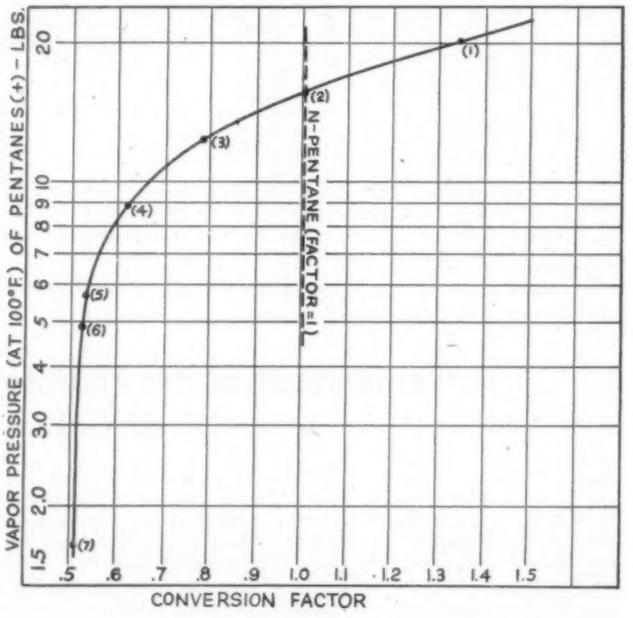


FIGURE 7

Chart to be Used in Conjunction with Figure 6 to Convert the Test Result Based on N-Petane for Variations in Pentanes (+) Quality

MATERIAL	Ref. No.	Grav. °API	Avg. B.P. °F.	V.P.	Conversion Factor
Isopentane	1	75.5	82.4	20.3	1.34
N-Pentane	2	92.5	97.2	15.5	1.00
Mixed Pentanes: A	3	79.2	146.	12.4	.78
Mixed Pentanes: B	4	71.8	175.	8.8	.62
Mixed Pentanes: C	5	58.7	218.	5.7	.53
N-Hexane	6	82.	156.	4.9	.52
N-Heptane	7	73.	209.	1.65	.51

liquid in the cooling coil. Remove the coil from the cooling bath and add more refrigerant in preparation for the absorption step. If several tests are to be run, draw two quarts of solvent and provide an extra supply of refrigerant.

Observe Barometric Pressure: Read and record the barometric pressure.

Sampling

Assemble Apparatus: Select a sampling point which will provide a representative sample of the residue gas to be tested, employing a center-line connection if possible. If a center-line connection is not available, an adequate scrubber shall be attached downstream from the rate control valve. Connect the test equipment as shown in Figure 3.

Purge Meter: With the equipment assembled as described above, up to but not including the absorption weathering tube, start a flow of gas through the meter for purging. While purging, check all connections on the outlet side of the meter for leaks, using a soap solution.

Add Solvent: Insert the absorption-weathering tube in the low-temperature cooling bath to a depth about 2 inches from the top of the absorption tube. Carefully add solvent. *High methane content* absorber residue gases will evaporate solvent. Therefore, 100 to 125 ml. may be added initially and enough more at intervals during the test to maintain the liquid level just above the top plate. Use excess solvent at start, but stop additions in time to end the test with the quiet level showing about 90 ml. with the plates in place. *Low methane content* vapor absorber residue gasses *may condense* to a considerable extent and increase the volume of absorbent. In testing these gases, 50 to 75 ml. of solvent shall be added initially and no more added during the test. In all cases, it is necessary that the volume at the end of the absorption step (gas shut off and plates removed) be not greater than 94 ml.

Start Gas: With the gas turned off, connect the absorption-weathering tube to the discharge of the drying tube, record the meter reading and start the flow of gas. The rate for absorption plant residue gasses shall normally be about 10 cubic feet per hour. For more condensable vapor absorber gases, the rate must be decreased to prevent the refrigerant in the low-temperature bath from boiling over. Keep the refrigerant level in the thermos bottle as high as possible, and in the P-W Test make sure that there is an excess amount of solid CO_2 snow present at all times.

Volume of Sample: To obtain the best results, it is desirable to absorb at least 1 ml. of pentanes(+) (B-W Test), or isobutane(+) (P-W Test). The volumes of gas corresponding to absorption of 1 ml. are as follows:

Estimate Pentanes(+) or Butanes(+) Content Gals./1000 Cu. Ft.	Gas Volume Corresponding to 1 ml. of Pentanes(+) or Butanes(+) Cu. Ft.
.01	26
.02	13
.03	8.8
.04	6.6
.05	5.3
.10	2.6
.20	1.3
.50	.53

Record Gas Volume: When a sufficient volume of sample has been tested, close the rate valve, disconnect the absorption-weathering tube, and record: (1) Test meter factor, (2) average test meter temperature (°F.), (3) average test meter pressure (mm.Hg.), and (4) final meter reading (cu.ft.).

Adjust Volume to 94 Ml.: with the absorption-weathering tube still in the cooling bath, close the inlet with a rubber tube and pinch clamp. Remove the screen plates and add solvent to bring the level to the 94 ml. mark. If the volume is more than 94 ml. (tolerance of 5 ml.), proceed as follows: (a) If the volume of absorbent decreases upon addition of gas, more gas may be passed through the absorption tube until the volume of liquid is reduced to 94 ml. (b) If the volume of absorbent increases upon addition of gas, the absorption step must be repeated using a reduced volume of solvent.

P-W Weathering Procedure

Add Charcoal: Just two grains of approximately 8-mesh new activated charcoal shall be placed in the absorption-weathering tube.

Support Weathering Tube: The absorption-weathering tube shall be removed from the cooling bath and supported by the neck, in a vertical position in air.

Weathering: The sample shall be allowed to weather without acceleration by removal of frost (except as may be necessary to read the temperature and volume), or by the application of heat in any form. This weathering shall be conducted in the shade, and the tube sheltered from the wind.

Insert Thermometer: When the residual volume is at the 85 ml. mark, suspend the precooled C.N.G.A. *Low* L.P.G. test thermometer in the weathering tube with the bulb as near the bottom as possible, but touching neither the charcoal nor the walls of the tube.

Refer to Figure 4 for Endpoint Temperature: The endpoint temperature (°F.) is fixed by the barometric pressure, or, if a barometer is unavailable, from elevation, by use of Figure 4.

Read Residue at Endpoint: Allow the boiling to continue without the application of heat until the endpoint temperature (—37° F. at 760 mm.) is reached. At the endpoint temperature quickly chill the liquid residue *just enough to stop boiling,* by *momentarily* touching the bottom tip of the tube in the cooling bath; remove the thermometer and read the residue volume.

Correct Metered Volume:

$$\text{Corrected Cu.Ft.} = M\left(\frac{520}{460+T}\right)\left(\frac{B+P}{30}\right)F$$

Where: M = Uncorrected metered volume, cu.ft.
T = Meter temperature, °F.
B = Barometric pressure, "Hg.
P = Meter pressure, "Hg.
F = Meter correction factor.

Interpretation of P-W Test Results

Apply Figure 5: Ml. isobutane(+) shall be derived from the residual volume at the endpoint temperature by use of Figure 5.

Calculate Isobutane(+) Gal./Mcf: From the corrected gas volume and the ml. isobutane(+) the enrichment of the residue gas (gal. isobutane(+)/1000 cu.ft. of gas) is computed from the equation:

$$\text{Isobut.(+) Gal./Mcf} = 0.264\left(1+\frac{\text{*Uncorrected Cu.Ft.}}{100}\right)\frac{\text{Ml. Isobutane(+)}}{\text{Corrected Cu.Ft.}}$$

* Correction for isobutane(+) material lost in gases leaving absorption-weathering tube.

B-W Weathering Test Procedure

Add Charcoal: Just two grains of approximately 8-mesh new activated charcoal shall be placed in the absorption-weathering tube.

Support Weathering Tube: The absorption-weathering tube shall be removed from the cooling bath and supported by the neck, in a vertical position, in air.

Weathering: The sample shall be allowed to weather without acceleration by removal of frost (except as may be necessary to read the temperature and volume), or by the application of heat in any form. This weathering shall be conducted in the shade, and the tube sheltered from the wind.

Use Water Bath: When the liquid in the absorption-weathering tube has weathered down to approximately the 85 ml. mark, the tube shall be lowered into the 60-70° F. water bath so that the tip is immersed in the water to the 1.5 ml. graduation.

Insert Thermometer: When the residual volume is at the 25 ml. mark, suspend the precooled C.N.G.A. *High* L.P.G. test thermometer in the weathering tube with the bottom of the bulb just above the 1.5 ml. graduation.

Weather in Air: When the residual volume is at the 15 ml. mark, raise the absorption-weathering tube from the bath and allow the weathering to continue in air without the application of outside heat.

Observe 10 Ml. Temperature: As the residual volume approaches the 10 ml. mark, watch the thermometer continuously and determine the temperature at the 10 ml. point with the thermometer in place.

Lower Thermometer: After taking the 10 ml. reading, lower the thermometer in the tube until the bulb is as near the bottom as possible, but is touching neither the charcoal nor the walls of the tube.

Refer to Figure 4 for Endpoint Temperature: The endpoint temperature (° F.) is fixed by the barometric pressure, or, if a barometer is unavailable, from elevation, by use of Figure 4.

Read Residue at Endpoint: Allow the boiling to continue without the application of heat until the endpoint temperature is reached, quickly chill the liquid residue *just enough to stop boiling* by *momentarily* touching the bottom tip of the tube in

the cooling bath, remove the thermometer and read the residue volume.

Correct Metered Volume:

$$\text{Corrected Cu.Ft.} = M\left(\frac{520}{460+T}\right)\left(\frac{B+P}{30}\right)F$$

Where: M = Uncorrected metered volume, cu.ft.
T = Meter temperature, °F.
B = Barometric pressure, "Hg.
P = Meter pressure, "Hg.
F = Meter correction factor.

Interpretation of B-W Test Results

Correct 10 Ml. Residue Temperature: The 10 ml. residue temperature shall be corrected for barometric pressure by use of Figure 4.

Apply Figure 6: The ml. pentanes(+), expressed as N-Pentane, shall be estimated from the corrected 10 ml. residue temperature and the residual volume at the endpoint by use of Figure 6.

Calculate Pentanes(+) Gal./Mcf: Assuming the pentanes(+) in the residue gas is equivalent to N-pentane, the $C_5(+)$ enrichment of the gas (gal./Mcf) is computed from the corrected gas Volume and ml. pentanes(+) residue by use of the following equation:

$$\text{Pentanes(+) Gal./Mcf} = 0.264\left(1+\frac{\dagger\text{Corrected Cu. Ft.}}{100}\right)\frac{\text{Ml. Pentanes(+)}}{\text{Corrected Cu. Ft.}}$$

† Correction for $C_5(+)$ material lost in gases leaving the absorption tube.

Conversion Factors for Different Pentanes(+) Materials: If the pentanes(+) in the residue gas is not equivalent to normal pentane, the gal./Mcf value obtained above (preceding paragraph) shall be multiplied by a conversion factor varying with properties of the $C_5(+)$ fraction. Conversion factors applicable to different vapor pressure $C_5(+)$ materials are shown in Figure 7. Factors applicable to typical absorber residue gases are as follows:

	Factors
Absorber residue $C_5(+)$ loss due to imperfect stripping	About 0.5
Absorber residue $C_5(+)$ loss due to incomplete absorption	About 1.0

Total Butanes

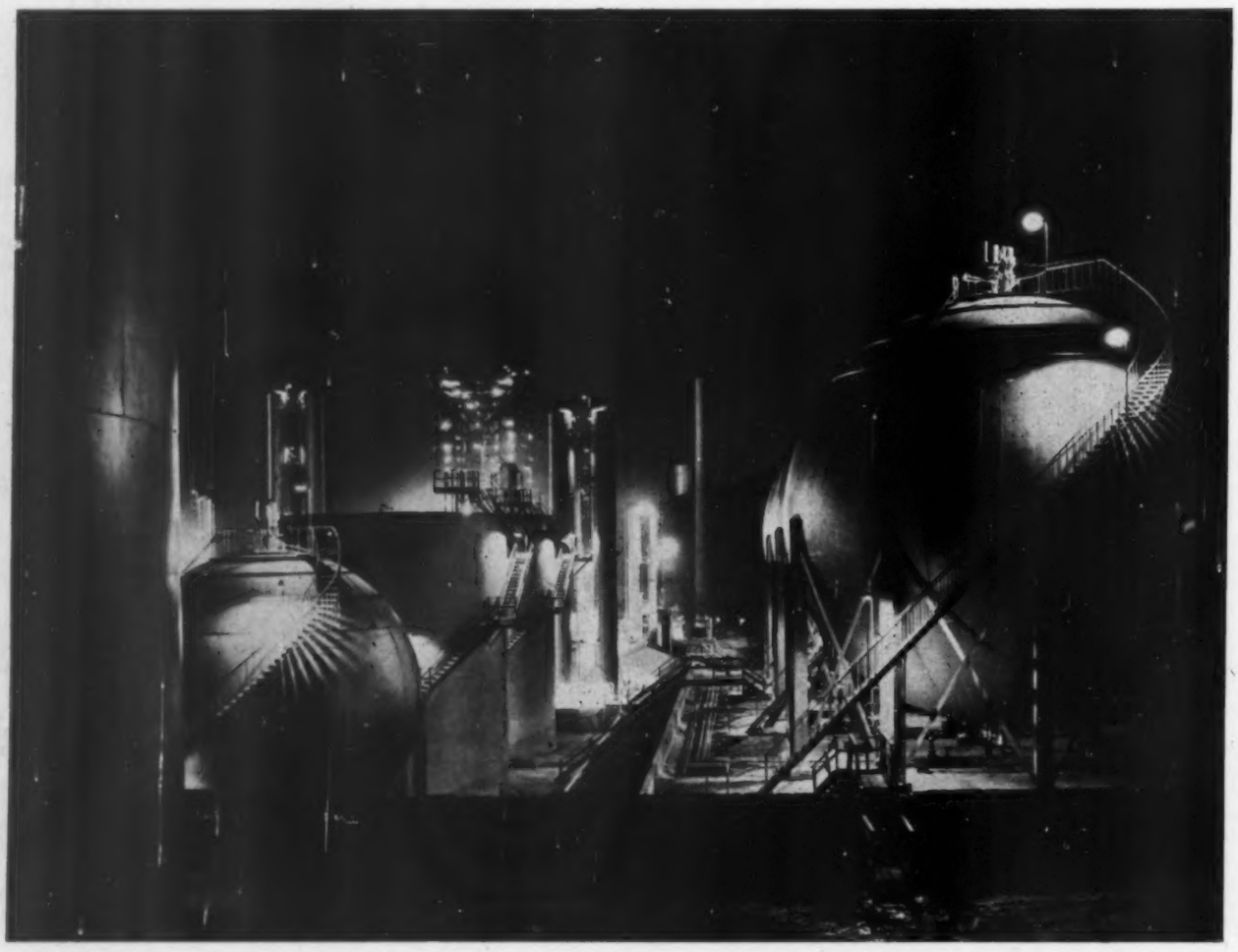
The total butanes content of the absorber residue gas is obtained by subtracting the B-W Test from the P-W Test:

Total Butanes (Gal./Mcf) =
P-W (Gal./Mcf) — *B-W* (Gal./Mcf)

Individual Isobutane and N-Butane Values

The individual butane values may be estimated on the basis of the iso versus normal ratio in the intake gas and relative extraction percentages. The latter may be computed from absorption factor theoretical plate relations. Assuming an 8-theoretical-plate absorber, the residue gas isobutane-normal butane split for different intake ratios and absorption factors will be as follows:

Isobutane Absorption Factor	Isobutane/Total Butanes in Intake Gas .25	.30	.35	.40
	Isobutane/Total Butanes in Residue Gas			
0.6	.38	.44	.50	.55
1.0	.60	.65	.70	.75
1.4	.70	.75	.79	.82



Night view of storage tanks at Standard Oil Company of California's Richmond Refinery.

Orifice Meter in Natural Gasoline Measurement

With Simplified Calculation Charts

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IN PROCESS and control applications, and to some extent in the sale and purchase of hydrocarbon fluids, the use of the orifice meter has long been an accepted standard means of measurement and much has been written concerning the theory and technique with respect to general and specific applications. This widespread use has quite naturally resulted in the development of various convenient charts and tables as calculation aids, but these have generally referred to gases and oil or heavy hydrocarbon liquids, and have not adequately covered the range of natural gasoline nor the light hydrocarbons such as ethane, propane and the butanes which are contained therein. After several years engaged in the handling of metering and control problems incident to the processing of natural gasoline and light hydrocarbons, the author has developed tabulations of metering factors for this application which presents the generally accepted basic data in a handy, usable form without sacrificing accuracy of calculation. These calculations apply to properly constructed meter runs and where the line static pressure is approximately one and one half greater than the vapor pressure of the flowing liquid. The basic general flow equation used in all orifice measurement of fluids is generally expressed as

$$Q = EAV \qquad (1)$$

in which, for liquid flow

Q = volume of flow per unit of time. = gallons per hour

E = the velocity and area coefficient of the orifice or orifice efficiency

A = cross sectional area of the orifice = square feet

V = average velocity of flow through the orifice = feet per second.

As applied to the measurement of water at 60° F. when "h" is the pressure differential across the orifice in inches of water, "d" is the orifice diameter and "D" is the pipe diameter in inches, the terms and the equation[6] become

$$V = \sqrt{2gh} = \sqrt{\frac{2 \times 32.16 \times h}{12}} = 2.32\sqrt{h}$$

$$A = \frac{\pi d^2}{4 \times 144} = 0.00545\, d^2$$

$$Q = 3600 \times E \times 0.00545\, d^2 \times 2.32\sqrt{h} \times 7.4805$$

$$= 340.09\, E\, d^2\sqrt{h} \qquad (2)$$

The "E" value is the coefficient of discharge when the Reynolds number is infinite, which is the minimum value for any particular orifice using flange taps. This has been determined to be a function of orifice and pipe diameters[1, 2, 4] as follows:

$$K_e = 0.5993 + \frac{0.007}{D} + \left(0.364 + \frac{0.076}{\sqrt{D}}\right)\left(\frac{d}{D}\right)^4 + 0.4\left(1.6 - \frac{1}{D}\right)^5 \left[\left(0.07 + \frac{0.5}{D}\right) - \frac{d}{D}\right]^{\frac{5}{2}} - \left(0.009 + \frac{0.034}{D}\right)\left(0.5 - \frac{d}{D}\right)^{\frac{3}{2}} + \left(\frac{65}{D^2} + 3\right)\left(\frac{d}{D} - 0.7\right)^{\frac{5}{2}}$$

$$E = d\left[830 - \frac{5000\,d}{D} + 9000\left(\frac{d}{D}\right)^2 - 4200\left(\frac{d}{D}\right)^3 + \frac{530}{\sqrt{D}}\right.$$

$$K_o = \frac{K_e}{1 + \frac{15\,E}{1{,}000{,}000\,d}}$$

Then, substituting in (2)

$$Q = \frac{340.09\, K_o\, d^2\sqrt{h}}{1 + \frac{15\,E}{1{,}000{,}000\,d}} \qquad (3)$$

Application of this basic flow equation has been simplified by the preparation of convenient charts and tables from which the required values and cor-

Gravity Degrees API Equivalent Specific Gravity 60°/60° F.

$$\text{Sp. Gr.} = \frac{141.5}{\text{API} + 131.5}$$

Deg. API	0	1	2	3	4	5	6	7	8	9
0	1.0760	1.0679	1.0599	1.0520	1.0443	1.0366	1.0291	1.0217	1.0143	1.0071
10	1.0000	.9930	.9861	.9792	.9725	.9659	.9593	.9529	.9965	.9402
20	.9340	.9279	.9218	.9159	.9100	.9042	.8984	.8927	.8871	.8816
30	.8762	.8708	.8654	.8602	.8550	.8498	.8448	.8398	.8348	.8299
40	.8251	.8203	.8155	.8109	.8063	.8017	.7972	.7927	.7883	.7839
50	.7796	.7753	.7711	.7669	.7628	.7587	.7547	.7507	.7467	.7428
60	.7389	.7351	.7313	.7275	.7238	.7201	.7165	.7128	.7093	.7057
70	.7022	.6988	.6953	.6919	.6886	.6852	.6819	.6787	.6754	.6722
80	.6690	.6659	.6628	.6597	.6566	.6536	.6506	.6476	.6446	.6417
90	.6388	.6360	.6331	.6303	.6275	.6247	.6220	.6193	.6166	.6139
100	.6112	.6086	.6060	.6034	.6008	.5983	.5958	.5933	.5908	.5884
110	.5859	.5835	.5811	.5787	.5764	.5740	.5717	.5694	.5671	.5649
120	.5626	.5604	.5582	.5560	.5538	.5517	.5495	.5474	.5453	.5432
130	.5411	.5394	.5370	.5350	.5330	.5310	.5290	.5270	.5250	.5231
140	.5212	.5193	.5174	.5155	.5136	.5117	.5099	.5045	.5063	.5044
150	.5027	.5009	.4991	.4974	.4956	.4939	.4922	.4905	.4888	.4871
160	.4854	.4838	.4821	.4805	.4788	.4772	.4756	.4740	.4725	.4709
170	.4693	.4678	.4662	.4647	.4632	.4617	.4602	.4587	.4572	.4557
180	.4543	.4528	.4514	.4499	.4485	.4471	.4457	.4443	.4429	.4415
190	.4401	.4388	.4374	.4361	.4347	.4334	.4320	.4307	.4294	.4281
200	.4268	.4256	.4243	.4230	.4218	.4205	.4193	.4180	.4168	.4156

TABLE 1

Basic Orifice Factors—Flange Taps

ORIFICE INCHES	PIPE SIZES 2-Inch Standard	3-Inch Standard	4-Inch Standard	6-Inch Standard	8-Inch Standard	10-Inch Standard	12-Inch Standard
.250	13.002	12.996	12.974	.....	.....	.....	.....
.375	29.079	29.026	28.989	.....	.....	.....	.....
.500	51.680	51.444	51.376	51.328	.....	.....	.....
.625	81.129	80.426	80.218	80.080	.....	.....	.....
.750	117.77	116.16	115.67	115.30	.....	.....	.....
.875	162.11	158.70	157.81	157.08	156.82	.....	.....
1.000	215.04	208.21	206.62	205.45	204.97	.....	.....
1.125	277.93	264.97	262.21	260.39	259.69	259.27	.....
1.250	353.04	329.41	324.72	321.93	320.94	320.35	320.00
1.375	443.44	402.10	394.35	390.11	388.73	387.95	387.47
1.500	554.71	483.80	471.35	464.98	463.10	462.07	461.44
1.625	.....	575.47	556.06	546.62	544.07	542.73	541.93
1.750	.....	678.61	648.93	635.11	631.64	629.94	628.93
1.875	.....	794.99	750.50	730.55	725.99	723.73	722.48
2.000	.....	926.76	861.42	833.06	826.86	824.11	822.56
2.125	.....	1076.6	982.50	942.83	934.59	931.10	929.21
2.250	.....	1251.2	1114.9	1060.0	1049.1	1044.7	1042.4
2.375	.....	.....	1259.9	1184.9	1170.5	1165.1	1162.3
2.500	.....	.....	1419.0	1317.7	1299.0	1292.1	1288.7
2.625	.....	.....	1593.9	1458.7	1434.4	1425.8	1421.7
2.750	.....	.....	1786.7	1608.3	1577.1	1566.4	1561.5
2.875	.....	.....	2000.3	1767.0	1727.1	1713.8	1707.9
3.000	.....	.....	2245.3	1935.2	1884.6	1868.2	1861.0
3.125	.....	.....	.....	2113.4	2049.7	2029.5	2020.9
3.250	.....	.....	.....	2302.4	2222.7	2197.8	2187.6
3.375	.....	.....	.....	2502.8	2403.7	2373.4	2361.1
3.500	.....	.....	.....	2715.7	2593.1	2556.1	2541.5
3.625	.....	.....	.....	2941.9	2791.1	2746.2	2728.9
3.750	.....	.....	.....	3182.5	2998.0	2943.8	2923.2
3.875	.....	.....	.....	3438.5	3214.2	3149.1	3124.6
4.000	.....	.....	.....	3711.4	3439.9	3362.1	3333.1
4.250	.....	.....	.....	4313.2	3922.0	3812.1	3772.0
4.500	.....	.....	.....	5013.1	4448.7	4295.5	4240.5
4.750	.....	.....	.....	.....	5024.8	4812.8	4739.6
5.000	.....	.....	.....	.....	5656.2	5369.9	5270.4
5.250	.....	.....	.....	.....	6349.6	5965.5	5834.0
5.500	.....	.....	.....	.....	7112.9	6604.3	6432.1
5.750	.....	.....	.....	.....	7956.0	7289.8	7066.1
6.000	.....	.....	.....	.....	8906.5	8026.3	7738.1
6.250	.....	.....	.....	.....	.....	8818.7	8450.0
6.500	.....	.....	.....	.....	.....	9672.0	9204.0
6.750	.....	.....	.....	.....	.....	10592	10006
7.000	.....	.....	.....	.....	.....	11587	10856
7.250	.....	.....	.....	.....	.....	12664	11759
7.500	.....	.....	.....	.....	.....	13851	12719
7.750	.....	.....	.....	.....	.....	.....	13741
8.000	.....	.....	.....	.....	.....	.....	14830

Basic Orifice Factor = 345.92 Ed^2.

rection factors for application thereto may be quickly selected for any set of flow conditions.

(1) Table 1[2] gives the basic orifice factors for flange taps for nominal line (D) and orifice size (d). Commercial measurement of liquids with an orifice meter using flange taps should be limited to a d/D ratio of .15 to .70. Table 2 (Supplement)[8] is included so that the exact basic orifice factor can be calculated based on the measured inside diameter of the upstream run and the measured orifice size.

The use of measured instead of nominal pipe diameters is necessary where maximum accuracy is desired since "standard pipe" is furnished in several inside diameters.

Note that the basic orifice constant used in these tables is 345.92 which is the A.G.A. basic constant for gas measurement. To convert to the water standard for liquid measurement a modulus of conversion of $\frac{340.09}{345.92}$ or 0.98316 must be applied.

(2) Measurement of the differential pressure across the orifice with a U-tube type, mercury-filled manometer requires that a correction be applied to the observed mercury differential equal to the weight of the column of sealing liquid in the manometer with a height of sealing liquid equal to the mercury differential.

Let, M_m = observed mercury differential

Then, M_w = correct water differential

$= (M_m \times 13.557) - (M_m \times$ Specific Gravity of Sealing Liquid)

$= (M_m \times 13.557) -$ (Differential Correction Factor)

Since, 1 inch mercury differential $= \frac{1}{13.557} = 0.07376$ inches water differential

Then, Differential Correction Factor when water is the sealing liquid equals $(1 - 0.07376)$

And, Differential Correction Factor for any sealing liquid equals (1 — 0.07376 Specific Gravity of Sealing Liquid).

Since the flow varies as the square root of the differential, the correction factor as applied in the flow equation becomes

$$\text{Liquid Over Mercury Factor} = \sqrt{1 - 0.07376 \text{ Sp. Gr. of Sealing Liquid}} \quad (4)$$

Application of the basic water flow equation (2) to the measurement of liquids other than water further requires that appropriate correction be applied for the specific gravity of the flowing liquid. Specific gravity of the liquid at flowing temperature can be obtained by hydrometer or density bomb and conversions to $\frac{60° \text{ F.}}{60° \text{ F.}}$ can be made from published tables.[7, 9]

The flowing specific gravity factor is

$$\text{Specific Gravity Factor} = \sqrt{\frac{1}{\text{Sp. Gr. @ flowing temperature}}} \quad (5)$$

To correct the volume measured at flowing tem-

TABLE 1 SUPPLEMENT

345.92 E—Factors

FLANGE TAPS:
d Actual Orifice Diameter Inches
D Actual Pipe I.D. Inches

d/D	0	1	2	3	4	5	6	7	8	9
0.10	206.00	205.97	205.95	205.92	205.90	205.87	205.84	205.82	205.79	205.77
0.11	205.74	205.72	205.70	205.69	205.67	205.65	205.63	205.61	205.60	205.58
0.12	205.56	205.55	205.53	205.52	205.51	205.50	205.48	205.48	205.46	205.44
0.13	205.43	205.42	205.42	205.41	205.41	205.40	205.39	205.39	205.38	205.38
0.14	205.37	205.37	205.37	205.36	205.36	205.36	205.36	205.36	205.35	205.35
0.15	205.35	205.35	205.35	205.35	205.36	205.36	205.36	205.36	205.37	205.37
0.16	205.38	205.38	205.39	205.40	205.40	205.41	205.42	205.42	205.43	20.544
0.17	205.45	205.46	205.47	205.48	205.48	205.49	205.51	205.52	205.53	205.54
0.18	205.56	205.57	205.58	205.60	205.61	205.62	205.64	205.65	205.66	205.68
0.19	205.69	205.71	205.72	205.74	205.75	205.77	205.78	205.80	205.81	205.83
0.20	205.84	205.86	205.88	205.89	205.90	205.92	205.94	205.95	205.97	205.98
0.21	206.00	206.01	206.03	206.04	206.06	206.08	206.09	206.11	206.12	206.14
0.22	206.15	206.17	206.18	206.20	206.22	206.23	206.25	206.26	206.28	206.30
0.23	206.31	206.33	206.34	206.36	206.38	206.39	206.41	206.42	206.44	206.46
0.24	206.47	206.49	206.51	206.52	206.54	206.56	206.57	206.59	206.61	206.63
0.25	206.64	206.66	206.68	206.69	206.71	206.73	206.75	207.76	206.78	206.80
0.26	206.82	206.84	206.85	206.87	206.90	206.91	206.92	206.94	206.96	206.98
0.27	206.99	207.02	207.04	207.05	207.07	207.09	207.11	207.13	207.15	207.17
0.28	207.19	207.21	207.23	207.24	207.26	207.28	207.30	207.32	207.34	207.36
0.29	207.38	207.41	207.43	207.45	207.47	207.49	207.51	207.53	207.55	207.57
0.30	207.59	207.62	207.64	207.66	207.68	207.70	207.72	207.74	207.77	207.79
0.31	207.81	207.83	207.86	207.88	207.90	207.92	207.95	207.97	207.99	208.02
0.32	208.04	208.06	208.09	208.11	208.14	208.16	208.18	208.21	208.23	208.26
0.33	208.28	208.31	208.34	208.36	208.38	208.41	208.44	208.46	208.49	208.51
0.34	208.54	208.57	208.59	208.62	208.65	208.67	208.70	208.73	208.76	208.78
0.35	208.81	208.84	208.87	208.90	208.92	208.95	208.98	209.01	209.04	209.07
0.36	209.10	209.13	209.16	209.19	209.22	209.25	209.28	209.31	209.34	209.37
0.37	209.40	209.44	209.47	209.50	209.53	209.57	209.60	209.63	209.66	209.70
0.38	209.73	209.76	209.80	209.83	209.87	209.90	209.94	209.97	209.99	210.04
0.39	210.08	210.11	210.15	210.18	210.22	210.26	210.29	210.33	210.37	210.40
0.40	210.44	210.48	210.52	210.56	210.59	210.63	210.67	210.71	210.75	210.79
0.41	210.83	210.87	210.91	210.95	210.99	211.04	211.08	211.12	211.16	211.20
0.42	211.24	211.29	211.33	211.37	211.42	211.46	211.50	211.55	211.59	211.64
0.43	211.68	211.73	211.77	211.82	211.86	211.91	211.96	212.00	212.05	212.10
0.44	212.15	212.19	212.24	212.29	212.34	212.39	212.44	212.49	212.54	212.59
0.45	212.64	212.69	212.74	212.79	212.84	212.90	212.95	213.00	213.05	213.11
0.46	213.16	213.22	213.27	213.32	213.38	213.43	213.49	213.54	213.60	213.66
0.47	213.71	213.77	213.83	213.88	213.94	214.00	214.06	214.12	214.18	214.24
0.48	214.30	214.36	214.42	214.48	214.54	214.60	214.67	214.73	214.79	214.85
0.49	214.92	214.98	215.04	215.11	215.17	215.24	215.30	215.37	215.44	215.50
0.50	215.57	215.64	215.70	215.77	215.84	215.91	215.97	216.04	216.11	215.18
0.51	216.25	216.32	216.39	216.46	216.54	216.61	216.68	216.76	216.83	216.90
0.52	216.98	217.05	217.13	217.21	217.28	217.36	217.44	217.51	217.59	217.67
0.53	217.75	217.83	217.91	217.99	218.07	218.15	218.23	218.31	218.39	218.48
0.54	218.56	218.64	218.73	218.81	218.90	218.98	219.07	219.16	219.24	219.23
0.55	219.42	219.51	219.60	219.69	219.78	219.87	219.96	220.05	220.14	220.24
0.56	220.33	220.42	220.52	220.61	220.71	220.80	220.90	221.00	221.09	221.19
0.57	221.29	221.39	221.49	221.59	221.69	221.79	221.89	221.99	222.10	222.20
0.58	222.30	222.41	222.50	222.62	222.72	222.83	222.94	223.04	223.15	223.26
0.59	223.37	223.48	223.59	223.70	223.81	223.92	224.03	224.15	224.26	224.38
0.60	224.49	224.60	224.72	224.84	224.96	225.07	225.19	225.31	225.43	225.55
0.61	225.67	225.79	225.91	226.04	226.16	226.28	226.41	226.53	226.66	226.78
0.62	226.91	227.04	227.17	227.30	227.43	227.56	227.69	227.82	227.95	228.08
0.63	228.22	228.35	228.48	228.62	228.76	228.89	229.03	229.17	229.30	229.44
0.64	229.58	229.72	229.87	230.01	230.15	230.29	230.44	230.58	230.73	230.87
0.65	231.03	231.16	231.31	231.46	231.61	231.76	231.91	232.06	232.21	232.37
0.66	232.52	232.68	232.83	232.99	233.14	233.30	233.46	233.62	233.77	233.94
0.67	234.10	234.26	234.42	234.58	234.74	234.91	235.08	235.24	235.41	235.58
0.68	235.74	235.91	236.08	236.25	236.42	236.60	236.77	236.94	237.12	237.29
0.69	237.47	237.64	237.82	238.00	238.18	238.36	238.54	238.72	238.90	239.08
0.70	239.27	239.45	239.64	239.83	239.99	240.21	240.40	240.59	240.78	240.98
0.71	241.17	241.37	241.57	241.78	241.98	242.19	242.40	242.61	242.82	243.03
0.72	243.25	243.47	243.69	243.91	244.14	244.36	244.59	244.82	245.06	245.30
0.73	245.54	245.80	246.02	246.27	246.52	246.77	247.02	247.28	247.54	247.80
0.74	248.06	248.33	248.60	248.88	249.15	249.43	249.71	250.00	250.28	250.57

perature to the standard condition of 60° F., the correction factor is

$$F_a = \frac{\text{Specific Gravity at Flowing Temperature}}{\text{Specific Gravity at 60° F.}} \qquad (6)$$

The total correction for the effects of flowing liquid specific gravity on the measured volume, when a U-tube type, mercury-filled manometer is used and when the flowing liquid is in contact with the mercury, may be expressed advantageously as a combination of (4), (5) and (6) when the final metered volume is to be determined at 60° F.

$$\text{Total Specific Gravity Correction} = \sqrt{\frac{1}{1 - 0.07376 \text{ Sp. Gr. @ 60° F.}}} \sqrt{\frac{1}{\text{Sp. Gr. @ flowing temperature}}} \times \frac{\text{Sp. Ga. @ flowing temperature}}{\text{Sp. Gr. @ 60° F.}}$$

$$= \sqrt{\frac{1 - 0.07376 \text{ Sp. Gr. @ 60° F.}}{\text{Sp. Gr. @ 60° F.} \times Fa}} \times \frac{\text{Sp. Gr. @ 60° F.} \times Fa}{\text{Sp. Gr. @ 60° F.}}$$

$$= \sqrt{\frac{1 - 0.07376 \text{ Sp. Gr. @ 60° F.}}{\text{Sp. Gr. @ 60° F.}}} \times \frac{Fa}{\sqrt{Fa}}$$

$$= \sqrt{\frac{1 - 0.07376 \text{ Sp. Gr. @ 60° F.}}{\text{Sp. Gr. @ 60° F.}}} \times \sqrt{Fa}$$

Table 2 presents, for specific gravities from 1.00 to 0.40, values of $0.98316 \sqrt{\frac{1 - 0.07376 \text{ Sp. Gr. @ 60° F.}}{\text{Sp. Gr. @ 60° F.}}}$ which corrects the basic orifice factor to a liquid constant and also partially corrects the effect of flowing liquid gravity. Table 3 presents, for temperatures over the range 31° F. to 190° F., values of $\sqrt{Fa}$. The curve shows the source from which the factors were derived. The area of lower specific gravity range factors (marked with arrows) were calculated from data published by the NGAA[9]; the remaining factors were calculated from data published by the National Standard Petroleum Oil Tables.[7] The extrapolated factors are given to make a more complete table and serve as a guide in process work when on rare instances these conditions exist.

Now, to sum up the factors affecting orifice measurement of liquids and to illustrate the use of the cited tables when using a mercury-filled U-tube and reading the mercury differential in terms of "h," the inches water differential

TABLE 2
Correction Factors for Specific Gravity Liquid

$$\text{Factor} = .98316 \sqrt{\frac{1 - .07376 \text{ Sp. Gr. at 60 °F.}}{\text{Sp. Gr. at 60 °F.}}}$$

Spec. Grav.	0	1	2	3	4	5	6	7	8	9
1.00	.9462	.9457	.9453	.9448	.9443	.9439	.9434	.9429	.9424	.9420
.99	.9509	.9505	.9500	.9496	.9491	.9487	.9483	.9478	.9474	.9469
.98	.9558	.9553	.9548	.9543	.9538	.9534	.9529	.9524	.9519	.9514
.97	.9610	.9605	.9600	.9594	.9589	.9584	.9579	.9574	.9568	.9563
.96	.9664	.9659	.9653	.9648	.9642	.9637	.9632	.9626	.9621	.9615
.95	.9720	.9714	.9709	.9703	.9698	.9692	.9686	.9681	.9675	.9670
.94	.9778	.9772	.9766	.9761	.9755	.9750	.9743	.9737	.9732	.9726
.93	.9837	.9831	.9825	.9819	.9813	.9808	.9802	.9796	.9790	.9784
.92	.9896	.9890	.9884	.9878	.9872	.9867	.9861	.9855	.9849	.9843
.91	.9955	.9949	.9943	.9937	.9931	.9926	.9920	.9914	.9908	.9902
.90	1.0014	1.0008	1.0002	.9996	.9990	.9985	.9979	.9973	.9967	.9961
.89	1.0073	1.0067	1.0061	1.0055	1.0049	1.0044	1.0038	1.0032	1.0026	1.0020
.88	1.0134	1.0128	1.0122	1.0116	1.0110	1.0104	1.0097	1.0091	1.0085	1.0079
.87	1.0197	1.0191	1.0184	1.0178	1.0172	1.0166	1.0159	1.0153	1.0147	1.0140
.86	1.0260	1.0254	1.0247	1.0241	1.0235	1.0229	1.0222	1.0216	1.0210	1.0203
.85	1.0325	1.0319	1.0312	1.0306	1.0299	1.0293	1.0286	1.0280	1.0273	1.0267
.84	1.0389	1.0383	1.0376	1.0370	1.0363	1.0357	1.0351	1.0344	1.0338	1.0331
.83	1.0456	1.0449	1.0443	1.0436	1.0429	1.0423	1.0416	1.0409	1.0402	1.0396
.82	1.0524	1.0517	1.0510	1.0504	1.0497	1.0490	1.0483	1.0476	1.0470	1.0463
.81	1.0593	1.0586	1.0579	1.0572	1.0565	1.0559	1.0552	1.0545	1.0538	1.0531
.80	1.0662	1.0655	1.0648	1.0641	1.0634	1.0628	1.0621	1.0614	1.0607	1.0600
.79	1.0735	1.0728	1.0720	1.0713	1.0706	1.0699	1.0691	1.0684	1.0677	1.0669
.78	1.0800	1.0801	1.0793	1.0786	1.0779	1.0772	1.0764	1.0757	1.0750	1.0742
.77	1.0882	1.0875	1.0867	1.0860	1.0852	1.0845	1.0838	1.0830	1.0823	1.0815
.76	1.0957	1.0950	1.0942	1.0935	1.0927	1.0920	1.0912	1.0905	1.0879	1.0890
.75	1.1034	1.1026	1.1019	1.1011	1.1003	1.0996	1.0988	1.0980	1.0972	1.0965
.74	1.1114	1.1106	1.1098	1.1090	1.1082	1.1074	1.1066	1.1058	1.1050	1.1042
.73	1.1194	1.1186	1.1178	1.1170	1.1162	1.1154	1.1146	1.1138	1.1130	1.1122
.72	1.1275	1.1267	1.1259	1.1251	1.1243	1.1235	1.1226	1.1218	1.1210	1.1202
.71	1.1359	1.1350	1.1342	1.1334	1.1325	1.1317	1.1309	1.1300	1.1292	1.1283
.70	1.1444	1.1436	1.1427	1.1419	1.1410	1.1402	1.1393	1.1385	1.1376	1.1368
.69	1.1532	1.1523	1.1514	1.1506	1.1497	1.1488	1.1479	1.1470	1.1462	1.1453
.68	1.1621	1.1612	1.1603	1.1594	1.1585	1.1577	1.1568	1.1559	1.1550	1.1541
.67	1.1711	1.1702	1.1693	1.1684	1.1675	1.1666	1.1657	1.1648	1.1639	1.1630
.66	1.1804	1.1795	1.1785	1.1776	1.1767	1.1758	1.1748	1.1739	1.1730	1.1720
.65	1.1899	1.1890	1.1800	1.1871	1.1861	1.1852	1.1842	1.1833	1.1823	1.1814
.64	1.1998	1.1988	1.1978	1.1968	1.1958	1.1949	1.1939	1.1929	1.1919	1.1909
.63	1.2096	1.2086	1.2076	1.2067	1.2057	1.2047	1.2037	1.2027	1.2018	1.2008
.62	1.2198	1.2188	1.2178	1.2167	1.2157	1.2147	1.2137	1.2127	1.2116	1.2106
.61	1.2303	1.2293	1.2282	1.2272	1.2261	1.2251	1.2240	1.2230	1.2219	1.2209
.60	1.2410	1.2399	1.2389	1.2378	1.2367	1.2357	1.2346	1.2335	1.2324	1.2314
.59	1.2519	1.2508	1.2497	1.2486	1.2475	1.2465	1.2454	1.2443	1.2432	1.2421
.58	1.2632	1.2621	1.2609	1.2598	1.2587	1.2576	1.2564	1.2553	1.2542	1.2530
.57	1.2747	1.2736	1.2724	1.2713	1.2701	1.2690	1.2678	1.2667	1.2655	1.2644
.56	1.2866	1.2854	1.2842	1.2830	1.2818	1.2807	1.2795	1.2783	1.2771	1.2759
.55	1.2986	1.2974	1.2962	1.2950	1.2938	1.2926	1.2914	1.2902	1.2890	1.2878
.54	1.3111	1.3099	1.3086	1.3074	1.3061	1.3049	1.3036	1.3024	1.3011	1.2999
.53	1.3240	1.3227	1.3214	1.3201	1.3188	1.3176	1.3163	1.3150	1.3137	1.3124
.52	1.3373	1.3360	1.3346	1.3333	1.3320	1.3307	1.3293	1.3280	1.3267	1.3253
.51	1.3509	1.3495	1.3482	1.3468	1.3455	1.3441	1.3427	1.3414	1.3400	1.3387
.50	1.3647	1.3633	1.3619	1.3606	1.3592	1.3578	1.3564	1.3550	1.3537	1.3523
.49	1.3789	1.3775	1.3761	1.3746	1.3732	1.3718	1.3704	1.3690	1.3675	1.3661
.48	1.3937	1.3922	1.3907	1.3893	1.3878	1.3863	1.3848	1.3833	1.3819	1.3804
.47	1.4090	1.4075	1.4059	1.4044	1.4029	1.4014	1.3998	1.3983	1.3968	1.3952
.46	1.4250	1.4234	1.4218	1.4202	1.4186	1.4170	1.4154	1.4138	1.4122	1.4106
.45	1.4411	1.4395	1.4379	1.4363	1.4347	1.4331	1.4314	1.4298	1.4282	1.4266
.44	1.4581	1.4564	1.4547	1.4530	1.4513	1.4496	1.4479	1.4462	1.4445	1.4428
.43	1.4754	1.4737	1.4719	1.4702	1.4685	1.4668	1.4650	1.4633	1.4616	1.4598
.42	1.4935	1.4917	1.4899	1.4881	1.4863	1.4845	1.4826	1.4808	1.4790	1.4772
.41	1.5122	1.5103	1.5085	1.5066	1.5047	1.5029	1.5010	1.4991	1.4972	1.4954
.40	1.5311	1.5292	1.5273	1.5254	1.5235	1.5217	1.5198	1.5179	1.5160	1.5140

$$\text{Gallons/Hr.} = \underbrace{345.92\ Ed^2}_{\text{Table 1}} \times \underbrace{0.98316 \sqrt{\frac{1 - 0.07376 \text{ Sp.Gr. @ 60° F.}}{\text{Sp. Gr. @ 60° F.}}}}_{\text{Table 2}} \times \underbrace{\sqrt{Fa}}_{\text{Table 3}} \times \sqrt{h} \qquad (7)$$

$$= \text{Table 1} \times \text{Table 2} \times \text{Table 3} \times \sqrt{h} \qquad (8)$$

$$\text{Hourly Coefficient} = \text{Table 1} \times \text{Table 2} \times \text{Table 3} \qquad (9)$$

The use of square-root charts to record the differential is recommended because the flow varies as the square root of the differential and a direct reading is thus obtained. The recommended minimum chart reading should be at least ¼ of the linear distance out on the chart.

Using a square-root chart to record the manometer differential, "h" the following factor will correct the chart reading "H" to the manometer range

$$\text{Square Root Chart Factor} = \frac{\sqrt{\text{Manometer Range}}}{\text{Chart Range}} \qquad (10)$$

Differential Range of Manometer Inches of Water	Square Root Chart Factor, Range 0 — 10
200	1.414
100	1.000
60	0.7746
50	0.7071
20	0.4472
10	0.3162

When using a square-root chart to record the dif-

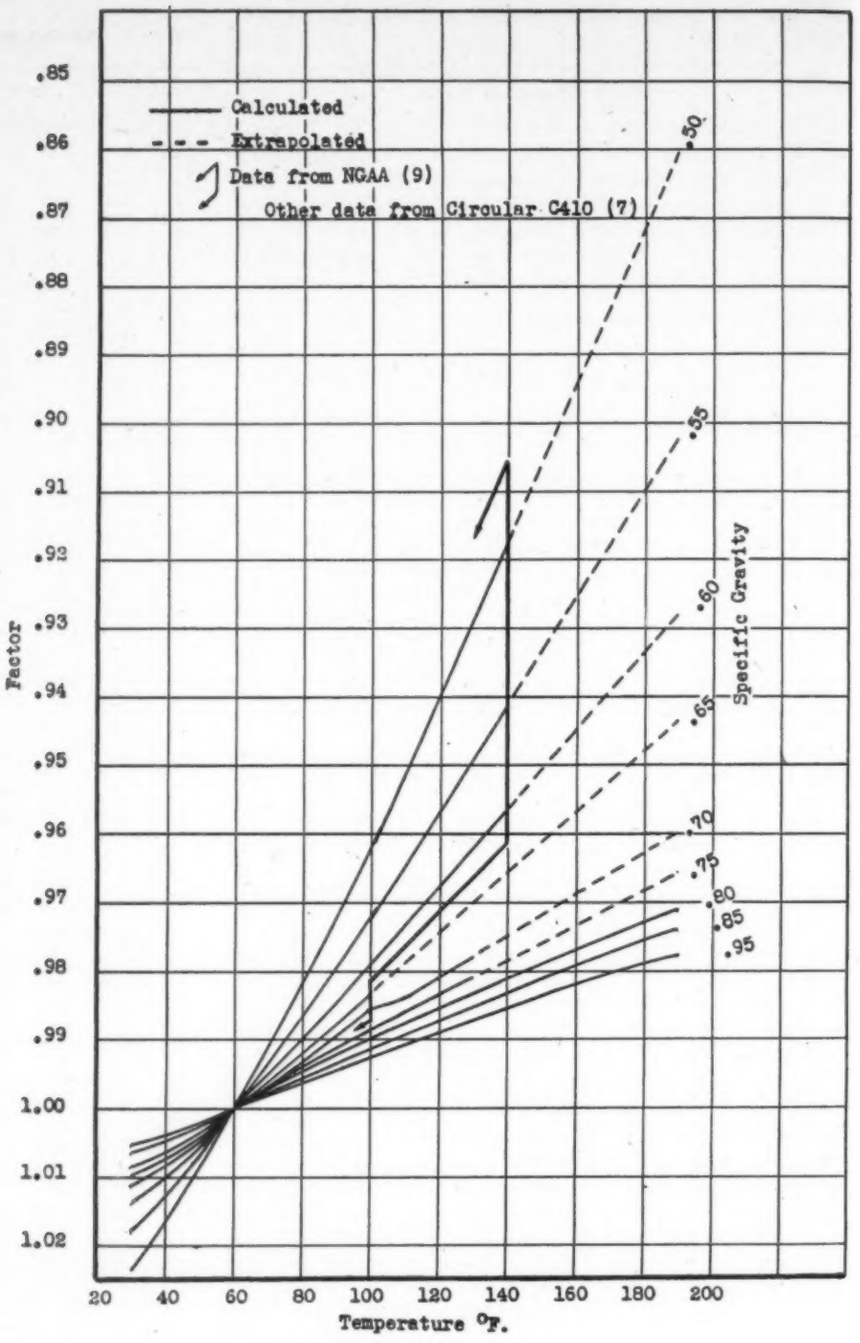

Chart for Table 3

ferential of a variable-range manometer equation (8) and (9) become

Gallons/Hr. =
Table 1 × Table 2 × Table 3 × Chart Factor × H (11)
and
Hourly Coefficient =
Table 1 × Table 2 × Table 3 × Chart Factor (12)

Application

Data:

Flange taps
Line and Orifice Plate Size 6.17-in. x 2.50-inch

Fluid Specific Gravity @ 60° F.	0.553
Flowing temperature	113°F.
Differential, inches of water	36

or, Differential, Root 8.49 when using a square-root chart with 50-inch manometer.

Problem A

Using a mercury-filled U-tube determine (a) hourly coefficient (b) volume based on nominal meter-run size and (c) volume based on actual measured upstream average inside diameter.

Solution A

(a) Substitute in Formula (9)
HourlyCoefficient = $1317.7 \times 1.2950 \times 0.9632 = 1644$.

(b) Substitute in Formula (8)
Gallons/Hour = $1644 \times \sqrt{36} = 9864$

(c) $\frac{d}{D} = \frac{2.50}{6.17} = 0.4052$

Table 1 supplement shows $345.92\ E = 210.64$
$345.92\ Ed^2 = 210.64\ (2.50)^2 = 1316.5$

Gallons/Hour (corr.) $= 9864 \times \frac{1316.5}{1317.7} = 9855$

Problem B

Using a 50-inch-range manometer with a 0-10-range square-root chart flow meter determine the (a) hourly coefficient (b) volume (c) maximum volume that can be measured with the 50-inch range manometer, and (d) maximum volume that can be measured by changing the manometer range from 50 to 100 inches.

Solution B

(a) Substitute in Formula (12)
Hourly Coefficient = $1317.7 \times 1.2950 \times 0.9632 \times 0.7071 = 1162$.

TABLE 3

Factors to Correct Volume to 60° F.

$$\sqrt{}\ \overline{F}$$

F is the factor to convert Sp.Gr. at 60°F to Sp.Gr. at T°F

Temp. °F.	.95	.90	.85	.80	.75	.70	.65	.60	.55	.50
31	1.0055	1.0059	1.0064	1.0076	1.0088	1.0100	1.0115	1.0140	1.0180	1.0235
32	1.0053	1.0056	1.0062	1.0072	1.0084	1.0097	1.0112	1.0135	1.0173	1.0227
33	1.0051	1.0054	1.0059	1.0069	1.0081	1.0093	1.0108	1.0130	1.0167	1.0219
34	1.0049	1.0052	1.0057	1.0066	1.0078	1.0089	1.0104	1.0125	1.0161	1.0212
35	1.0047	1.0050	1.0055	1.0064	1.0075	1.0085	1.0100	1.0120	1.0155	1.0205
36	1.0045	1.0048	1.0053	1.0061	1.0072	1.0082	1.0096	1.0115	1.0149	1.0197
37	1.0043	1.0046	1.0051	1.0059	1.0069	1.0079	1.0092	1.0110	1.0143	1.0189
38	1.0041	1.0044	1.0048	1.0056	1.0066	1.0076	1.0088	1.0105	1.0137	1.0181
39	1.0039	1.0042	1.0046	1.0054	1.0063	1.0073	1.0084	1.0100	1.0131	1.0173
40	1.0038	1.0040	1.0044	1.0051	1.0060	1.0070	1.0080	1.0095	1.0125	1.0165
41	1.0036	1.0038	1.0042	1.0048	1.0056	1.0066	1.0076	1.0091	1.0119	1.0157
42	1.0034	1.0036	1.0040	1.0046	1.0053	1.0062	1.0072	1.0087	1.0113	1.0149
43	1.0032	1.0034	1.0037	1.0043	1.0050	1.0058	1.0068	1.0083	1.0107	1.0141
44	1.0030	1.0032	1.0035	1.0041	1.0047	1.0054	1.0064	1.0079	1.0101	1.0133
45	1.0028	1.0030	1.0033	1.0038	1.0044	1.0050	1.0060	1.0075	1.0095	1.0125
46	1.0026	1.0028	1.0031	1.0036	1.0041	1.0047	1.0056	1.0070	1.0089	1.0117
47	1.0024	1.0026	1.0029	1.0033	1.0038	1.0044	1.0052	1.0065	1.0083	1.0109
48	1.0023	1.0024	1.0026	1.0031	1.0035	1.0041	1.0048	1.0060	1.0077	1.0101
49	1.0021	1.0022	1.0024	1.0028	1.0032	1.0038	1.0044	1.0055	1.0071	1.0093
50	1.0019	1.0020	1.0022	1.0025	1.0029	1.0035	1.0040	1.0050	1.0065	1.0085
51	1.0017	1.0018	1.0020	1.0023	1.0026	1.0031	1.0036	1.0045	1.0058	1.0077
52	1.0015	1.0016	1.0018	1.0020	1.0023	1.0027	1.0032	1.0040	1.0051	1.0069
53	1.0013	1.0014	1.0015	1.0018	1.0020	1.0023	1.0028	1.0035	1.0044	1.0061
54	1.0011	1.0012	1.0013	1.0015	1.0017	1.0019	1.0024	1.0030	1.0037	1.0053
55	1.0009	1.0010	1.0011	1.0013	1.0014	1.0015	1.0020	1.0025	1.0030	1.0045
56	1.0008	1.0008	1.0009	1.0010	1.0011	1.0012	1.0016	1.0020	1.0024	1.0036
57	1.0006	1.0006	1.0007	1.0008	1.0008	1.0009	1.0012	1.0015	1.0018	1.0027
58	1.0004	1.0004	1.0004	1.0005	1.0006	1.0006	1.0008	1.0010	1.0012	1.0018
59	1.0002	1.0002	1.0002	1.0003	1.0003	1.0003	1.0004	1.0005	1.0006	1.0009
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
61	.9998	.9998	.9998	.9998	.9997	.9997	.9996	.9995	.9993	.9991
62	.9996	.9996	.9996	.9995	.9994	.9994	.9992	.9990	.9986	.9982
63	.9994	.9994	.9993	.9993	.9991	.9991	.9988	.9985	.9979	.9973
64	.9992	.9992	.9991	.9990	.9988	.9988	.9984	.9980	.9972	.9964
65	.9991	.9990	.9989	.9988	.9985	.9985	.9980	.9975	.9965	.9955
66	.9989	.9988	.9987	.9986	.9982	.9981	.9976	.9970	.9959	.9947
67	.9987	.9986	.9985	.9983	.9980	.9977	.9972	.9965	.9953	.9939
68	.9985	.9984	.9982	.9981	.9977	.9973	.9968	.9960	.9947	.9931
69	.9983	.9982	.9980	.9978	.9974	.9969	.9964	.9955	.9941	.9923
70	.9981	.9980	.9977	.9976	.9972	.9965	.9960	.9950	.9935	.9915
71	.9979	.9977	.9975	.9972	.9969	.9962	.9956	.9945	.9928	.9906
72	.9977	.9975	.9973	.9970	.9966	.9959	.9952	.9940	.9921	.9897
73	.9976	.9973	.9971	.9967	.9963	.9956	.9948	.9935	.9914	.9888
74	.9974	.9971	.9968	.9964	.9960	.9953	.9944	.9930	.9907	.9879
75	.9972	.9969	.9966	.9961	.9957	.9950	.9940	.9925	.9899	.9869
76	.9970	.9967	.9964	.9958	.9954	.9946	.9936	.9920	.9893	.9859
77	.9968	.9965	.9962	.9956	.9952	.9942	.9932	.9915	.9887	.9850
78	.9967	.9963	.9960	.9954	.9949	.9938	.9928	.9909	.9881	.9841
79	.9965	.9961	.9958	.9952	.9947	.9934	.9924	.9904	.9875	.9832
80	.9963	.9959	.9956	.9950	.9944	.9930	.9920	.9899	.9869	.9823
81	.9961	.9957	.9954	.9948	.9941	.9926	.9916	.9894	.9863	.9813
82	.9959	.9956	.9952	.9945	.9938	.9922	.9912	.9889	.9856	.9805
83	.9958	.9954	.9950	.9943	.9936	.9918	.9908	.9884	.9848	.9796
84	.9956	.9952	.9948	.9941	.9933	.9914	.9904	.9879	.9841	.9787
85	.9954	.9950	.9946	.9938	.9930	.9910	.9899	.9874	.9834	.9778
86	.9952	.9948	.9944	.9936	.9927	.9906	.9895	.9869	.9827	.9768
87	.9950	.9946	.9942	.9933	.9924	.9903	.9891	.9862	.9820	.9759
88	.9949	.9945	.9940	.9931	.9922	.9999	.9887	.9856	.9812	.9749
89	.9947	.9943	.9938	.9929	.9919	.9996	.9883	.9850	.9805	.9740
90	.9945	.9940	.9936	.9926	.9916	.9892	.9879	.9844	.9798	.9730

Temp. °F.	.95	.90	.85	.80	.75	.70	.65	.60	.55	.50
91	.9943	.9938	.9934	.9923	.9913	.9888	.9874	.4938	.9791	.9720
92	.9941	.9936	.9932	.9921	.9910	.9885	.9869	.9833	.9784	.9710
93	.9940	.9934	.9930	.9919	.9908	.9881	.9864	.9828	.9776	.9700
94	.9938	.9932	.9928	.9917	.9905	.9878	.9859	.9823	.9769	.9790
95	.9936	.9930	.0026	.9914	.9902	.9874	.9854	.9818	.9762	.9680
96	.9934	.9928	.9924	.9912	.9899	.9870	.9850	.9813	.9755	.9670
97	.9933	.9927	.9922	.9909	.9896	.9867	.9846	.9808	.9748	.9660
98	.9931	.9925	.9920	.9907	.9894	.9863	.9842	.9803	.9740	.9649
99	.9930	.9923	.9918	.9904	.9891	.9859	.9838	.9798	.9733	.9639
100	.9928	.9922	.9916	.9902	.9888	.9856	.9834	.9793	.9726	.9628
101	.9926	.9920	.9914	.9900	.9885	.9857	.9830	.9788	.9719	.9618
102	.9924	.9918	.9912	.8989	.9883	.9855	.9826	.9783	.9711	.9607
103	.9923	.9916	.9910	.9895	.9880	.9853	.9821	.9777	.9704	.9597
104	.9921	.9914	.9908	.9893	.9877	.9851	.9817	.9772	.9697	.9586
105	.9919	.9912	.9906	.0890	.9875	.9849	.9813	.9767	.9690	.9576
106	.9917	.9910	.9903	.9888	.9873	.9847	.9808	.9762	.9683	.9565
107	.9915	.9908	.9901	.9885	.9870	.9845	.9804	.9757	.9676	.9555
108	.9914	.9906	.9899	.9883	.9868	.9843	.9800	.9752	.9668	.9545
109	.9912	.9904	.9897	.9881	.9865	.9841	.9795	.9747	.9661	.9534
110	.9910	.9902	.9895	.9879	.9863	.9839	.9791	.9742	.9654	.9524
111	.9908	.9900	.9893	.9877	.9861	.9833	.9787	.9737	.9647	.9513
112	.9906	.9898	.9891	.9875	.9858	.9831	.9783	.9732	.9640	.9503
113	.9905	.9896	.9889	.9872	.9856	.9828	.9778	.9727	.9632	.9492
114	.9903	.9894	.9887	.9870	.9853	.9826	.9774	.9722	.9625	.9482
115	.9901	.9892	.9885	.9868	.9851	.9823	.9769	.9716	.9618	.9471
116	.9899	.9890	.9883	.9865	.9848	.9820	.9765	.9710	.9611	.9460
117	.9898	.9888	.9881	.9863	.9846	.9817	.9760	.9704	.9603	.9450
118	.9896	.9886	.9879	.9860	.9843	.9815	.9756	.9798	.9596	.9439
119	.9894	.9885	.9877	.9859	.9841	.9812	.9751	.9792	.9588	.9429
120	.9892	.9883	.9475	.9857	.9838	.9809	.9747	.9685	.9581	.9418
121	.9890	.9881	.9873	.9855	.9835	.9805	.9743	.9680	.9573	.9406
122	.9888	.9879	.9871	.9852	.9833	.9803	.9738	.9675	.9565	.9394
123	.9887	.9877	.9869	.9850	.9830	.9800	.9734	.9670	.9557	.9383
124	.9885	.9876	.9867	.9848	.9829	.9797	.9730	.9665	.9549	.9371
125	.9883	.9874	.9865	.9846	.9825	.9794	.9726	.9659	.9541	.9359
126	.9882	.9872	.9863	.9843	.9823	.9791	.9721	.9653	.9532	.9347
127	.9880	.9870	.9861	.9841	.9820	.9788	.9717	.9647	.9524	.9336
128	.9879	.9868	.9860	.9839	.9818	.9786	.9713	.9640	.9515	.9324
129	.9877	.9866	.9858	.9836	.9815	.9783	.9708	.9634	.9507	.9313
130	.9875	.9865	.9856	.9834	.9813	.9780	.9704	.9628	.9499	.9301
131	.9873	.9863	.9854	.9832	.9810	.9777	.9699	.9622	.9490	.9289
132	.9871	.9861	.9852	.9830	.9808	.9774	.9695	.9616	.9481	.9277
133	.9870	.9859	.9851	.9827	.9805	.9771	.9690	.9609	.9473	.9265
134	.9868	.9857	.9849	.9825	.9803	.9768	.9686	.9603	.9464	.9253
135	.9866	.9856	.9847	.9823	.9800	.9765	.9681	.9597	.9455	.9241
136	.9864	.9854	.9845	.9821	.9797	.9762	.9676	.9591	.9447	.9228
137	.9863	.9852	.9842	.9819	.9795	.9759	.9672	.9585	.9438	.9215
138	.9861	.9850	.9840	.9816	.9792	.9756	.9667	.9578	.9430	.9202
139	.9860	.9849	.9839	.9814	.9790	.9753	.9663	.9572	.9421	.9189
140	.9858	.9847	.9836	.9812	.9787	.9750	.9658	.9566	.9413	.9176
145	.9850	.9839	.9826	.9802	.9774	.9735	.9636	.9537	.9392	.9119
150	.9842	.9829	.9815	.9793	.9761	.9720	.9614	.9509	.9370	.9063
155	.9833	.9819	.9807	.9783	.7948	.9705	.9592	.9480	.9349	.9006
160	.9824	.9810	.9798	.9773	.9735	.9690	.9570	.9452	.9328	.8950
165	.9816	.9801	.9789	.9764	.9722	.9675	.9548	.9423	.9307	.8893
170	.9808	.9792	.9780	.9754	.9709	.9660	.9526	.9394	.9285	.8836
175	.9800	.9783	.9771	.9744	.9696	.9645	.9504	.9366	.9264	.8780
180	.9793	.9773	.9762	.9734	.9683	.9603	.9482	.9337	.9243	.8723
185	.9785	.9764	97.52	.9725	.9670	.9615	.9460	.9309	.9221	.8667
190	.9778	.9755	.9743	.9715	.9657	.9600	.9438	.9280	.9200	.8610

(b) Substitute in Formula (11)
Gallons/Hour = $1162 \times 8.49 = 9865$.

(c) Substitute in Formula (11)
Maximum Gallons/Hour = $1162 \times 10 = 11620$.

(d) Substitute in Formula (11)
Maximum Gallons/Hour = $1317.7 \times 1.2950 \times 0.9632 \times 1.0 \times 10 = 16440$.

Problem C

Calculate the orifice plate size necessary to measure 9000 gallons per hour at approximately 7 root chart reading.

Solution C

Solve Formula (11) for Table 1 and substitute

$$\text{Table 1} = \frac{\text{Volume G.P.H.}}{\text{Table 2} \times \text{Table 3} \times \text{Chart Factor} \times \text{H}}$$

$$= \frac{9000}{1.2950 \times 0.9632 \times 0.7071 \times 7}$$

$$= 1458.$$

According to Table 1
6-inch meter run with 2.625-inch orifice or 4-inch meter with 2.50-inch orifice.

ACKNOWLEDGEMENT

The author wishes to thank Phillips Petroleum Company for permission to print this article and to express appreciation to H. R. Legatski for his aid in the composition of this article.

Note: Statements or opinions advanced in this paper are understood to be the author's individual expression and not those of Phillips Petroleum Company.

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Crude Oil De-Salting In Refinery Operations

F. DUANE FUQUA, Ben Franklin Refining Company, Ardmore, Oklahoma

IT IS well known that salt is responsible for a great deal of refinery corrosion and deposition in topping, cracking and exchanger tubes. Chlorides are particularly offensive since by hydrolysis they form hydrochloric acid which reacts with iron to form iron chloride. Hydrogen sulfide present in some oils reacts on the iron chloride to form iron sulfide and liberate hydrogen chloride which again attacks iron, and the process is repeated.

Whenever salt-containing oils are evaporated, the salt is precipitated, thus adhering to tube walls and progressively reducing the efficiency of heaters and exchangers both by decreasing heat-transfer coefficients as well as substantially increasing pressure drop.

Most salt-removal systems are similar in that they are integrated into essentially three main parts.

1. Introduction of water to the crude oil.
2. Emulsification of water and crude oil.
3. Demulsification of crude oil.

The greatest difference between salt-removal systems is in the method utilized in carrying out each step.

THIS paper has no intention of setting forth a sure-all salt-removal method as it is realized that the problems of crude-oil desalting are wide spread.

The method herein described utilizes well known fundamentals of salt removal. The results are pleasing in that 90 percent and better salt removal is constantly obtained with a chemical cost of less than two mills per barrel of crude processed.

Throughout this discussion the word "salt" refers to the chloride content whatever the positive radical may be.

This paper was presented before Western Petroleum Refiners Association annual meeting, Fort Worth, Texas, March 25-27, 1946.

The process as utilized at Ben Franklin Refining Company's refinery, as shown by Figure 1, involves introduction of a metered quantity of preheated water

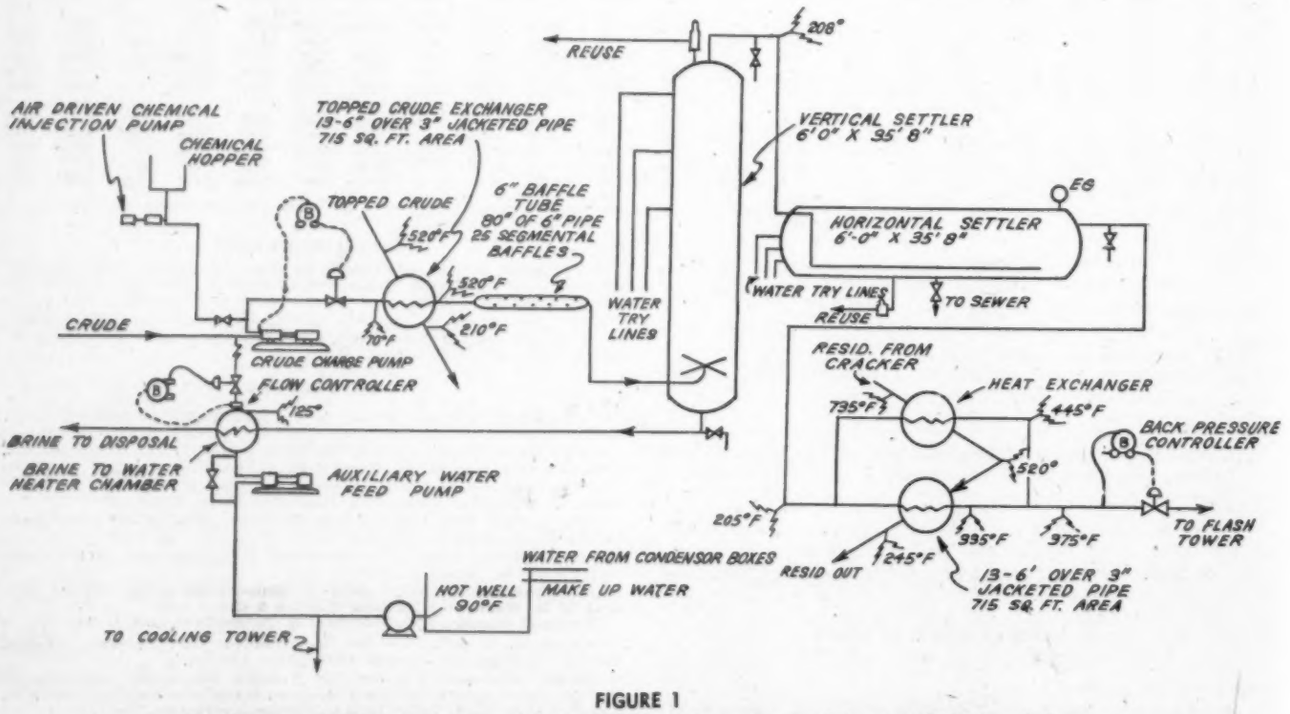


FIGURE 1

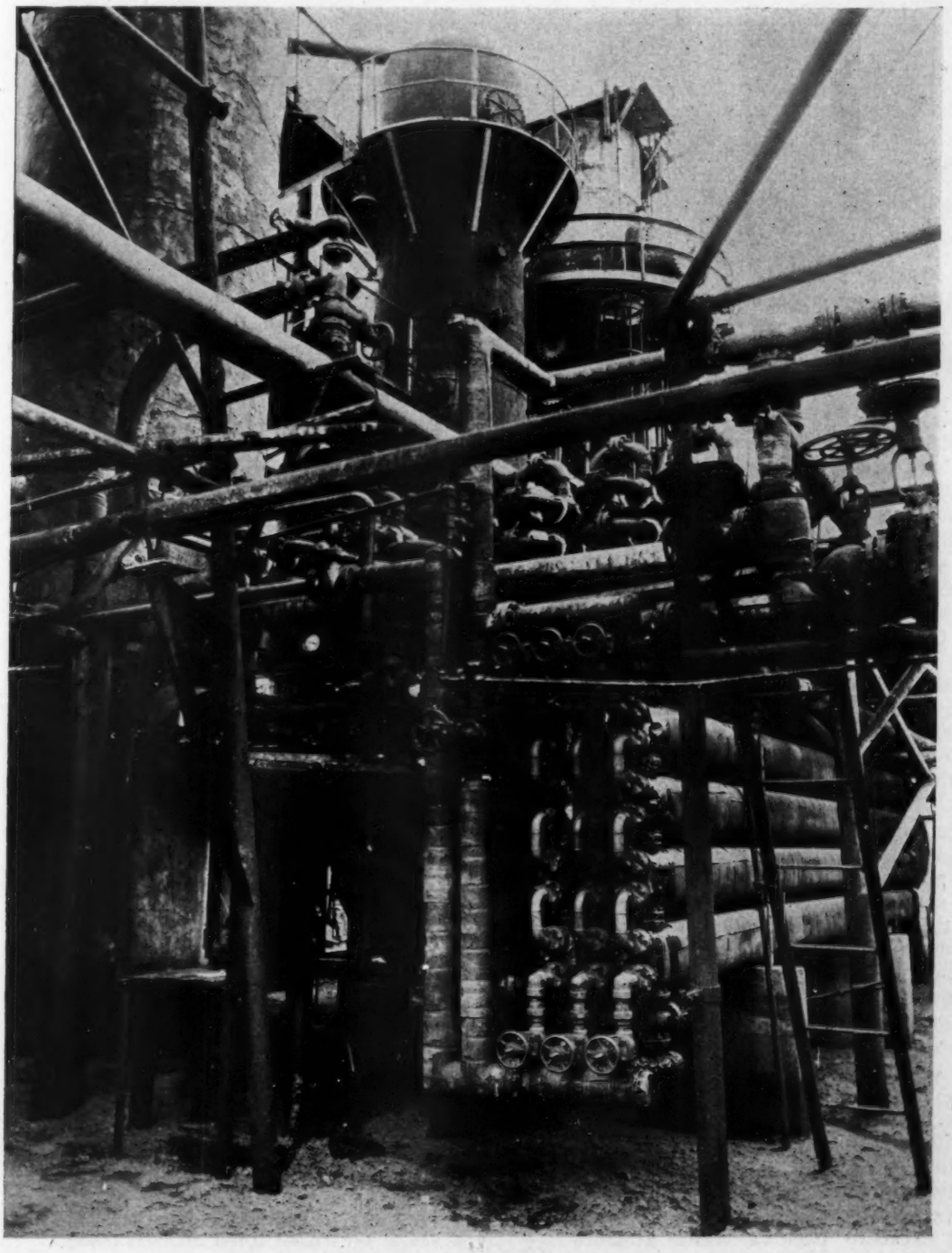
Flow Diagram—Salt Removal Equipment at Ben Franklin Refinery Company's Ardmore, Oklahoma, Refinery.

five pipe diameters from the suction of a reciprocating crude-oil charge pump. Water used is from the discharge of the cooling-water-circulating pump which takes suction from a hot well that receives the hot effluent from several condenser boxes. Make up water to the hot well comes from a pond filled by surface water. The water has a relatively low hardness, but often contains considerable amounts of dissolved and suspended solids. The water-circulating pump produces sufficient head to put the required amount of processing water through a brine-to-water exchanger and into the suction of the crude pump. However, should more pressure be desired, a small reciprocating pump has been provided.

An orifice has been installed on the water line and a flow-control indicator allows the operator to know at all times how much water is being injected. Valves allow the water line to be blocked from the crude and by-passed to a barrel to permit calibration of the meter at regular intervals as a safeguard against orifice fouling or mechanical trouble within the flow indicator.

Water from the hot well is 90-100° F., and is raised to approximately 130° F. by heat exchange with the effluent brine which is drained to a spare tank until such time as it may be disposed of.

Demulsifying chemical, as required, is pumped by means of an air-driven chemical-injection pump into the crude five pipe diameters downstream from the crude-pump discharge. Chemical rates are easily adjusted by length of pump strokes, speed of pump, and number of cylinders operated. The quantity of chemical is obtained by direct gauge from small hoppers. Operators are responsible for quantity of chemical



The center tower is the vertical salt settler (see flow chart on opposite page). The heat exchangers in the immediate foreground are the residue-to-crude exchangers. The horizontal settler may be seen immediately behind these exchangers, while the topped-crude-to-crude exchangers are above the horizontal settler.

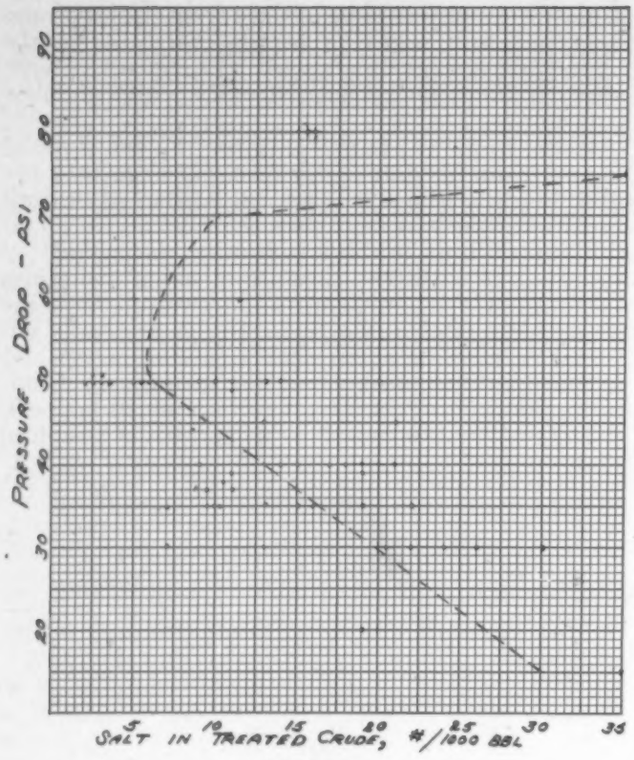


FIGURE 2
△P vs. salt in washed crude. (Other conditions varying.)

used and are at all times cognizant of the amount being used per shift.

Water emulsion is formed by passing the crude and water mixture through an air-operated, double-port, throttle-type back-pressure-control valve. The valve is set to hold a given back pressure on the crude-oil pump, thus controlling the amount of pressure drop required for emulsion.

Next the emulsion passes through a topped-crude-to-crude heat exchanger where sufficient heat is picked up to break the viscosity of the oil. Exchangers now being used for this service are 13 60-foot lengths of 6-inch over 3-inch jacketed standard pipe connected in series. With 751 square feet of external tube surface the mixture of oil and water is heated from 70° F. to approximately 210° F., while the 60-65 percent yield of topped crude is cooled from 520 to 235° F. Crude is piped through the tube side and topped crude passes through the shell counter currently.

Crude passes directly from the heat exchangers into a horizontal baffle tube. The baffle is fabricated of 80 feet of 6-inch pipe with 25 segmental baffles, slightly larger than semicircle, welded into the pipe at regular intervals. Pressure-gauge connections have been installed before and after the baffle, which also may be used for sample connections, or water- or chemical-insertion points (they have never been used as such during the course of this investigation).

From the outlet of the baffle tube, crude enters the bottom head of a 6-foot by 35-foot, 8-inch vertical settler. The feed nozzle of the vertical ells up into the vertical and terminates in a cross distribution header. The vertical vessel contains a perforated plate with 1-inch holes on 2-inch centers located directly below the top manway 6 feet from the top of the vessel. The plate presently has no use, but at one time supported an excelsior packing which at the time proved to be worthless. Try-cocks are located 20 feet, 24½ feet, and 29 feet from the bottom of the vertical vessel. A water level of approximately 20 feet is maintained in the vertical and crude is scrubbed counter currently with water breaking from the emulsion.

Hot water is drawn from the vertical settler and exchanges heat with the fresh water charge. The brine drawn-off is hand controlled. Water-washed crude passes from the top of the vertical vessel into a 6-foot by 35-foot, 8-inch horizontal settler where additional settling time is afforded. Actually the horizontal vessel is in the system only as a safety factor.

Crude enters the horizontal vessel through a perforated distribution header which runs longitudinally the full length of the vessel. This header originally was intended for additional water scrubbing through a water level held in the horizontal. Crude outlet is on top of the head opposite the feed entry. Try-cocks are provided on the horizontal drum; also water may be drawn from the bottom of the vessel to the sewer.

A pressure gauge on the outlet of the horizontal serves as an index for the back pressure that is held on the outlet of further exchangers.

Crude from the horizontal is split through two exchangers where heat is picked up from cracking-plant residuum. One is a fin-tube unit piped series parallel 24 tubes—3 banks of 8 tubes, with 1368 square feet of external surface, exchanging heat with hot residuum (735-520° F.) directly from the cracking plant. The other exchanger is identical in construction with the topped-crude-to-crude exchanger, i.e. 13 60-foot lengths of 6-inch over 3-inch jacketed pipe with crude on tube side and residuum effluent from the fin-tube exchanger on the shell side (520-245° F.).

Under normal plant operation 375° F. crude preheat is obtained up to this point.

A 2-inch back-pressure control is located on the effluent of the exchangers. Enough back pressure is

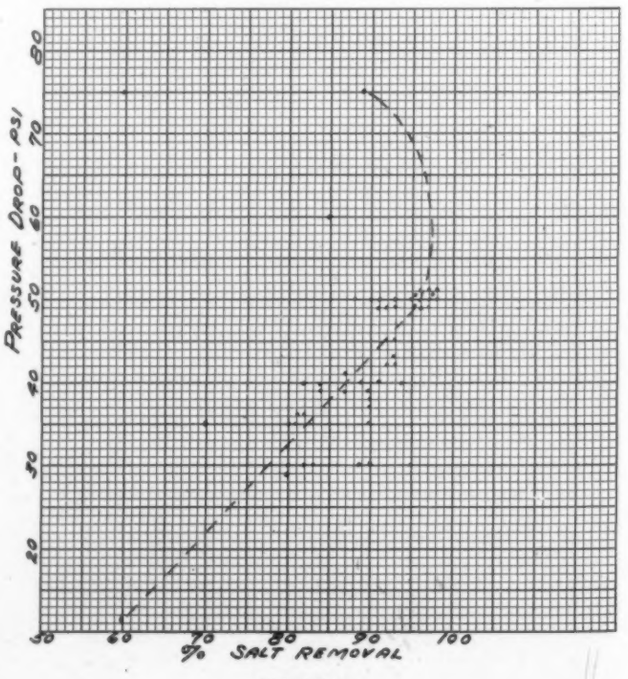


FIGURE 3
△P vs. percent salt removal. (Other conditions varying.)

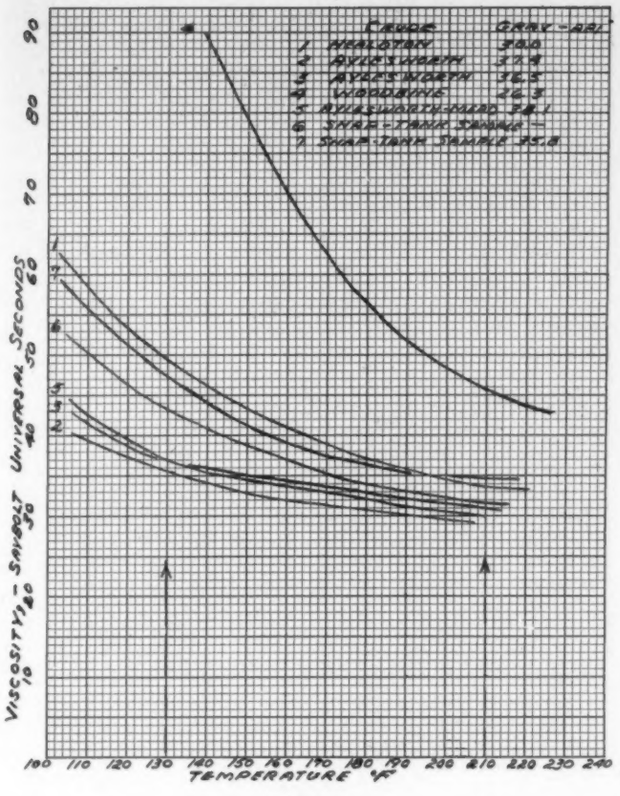


FIGURE 4
Temperature vs. viscosity curves of Ben Franklin crude oils.

held at this point to prevent vaporization within the exchangers and to maintain a back pressure on the horizontal settler of 125 to 140 pounds.

Crude then passes to a flash tower where approximately 10 percent of the crude is flashed to the fractionators and the tower bottoms are charged to the furnace.

In order to effect the greatest salt removal it is necessary that the salt be given every opportunity to contact water. Thus it was believed that water-wash in addition to the original emulsification would be beneficial. However, any number of water-washes is of no benefit if the film of the emulsifying agent is not broken, since this film encases dispersed droplets of brine. The smaller the droplets the "tighter" the emulsion and the more difficult it is to break. So far as possible, the emulsion must be made to fit the crude; conversely the demulsification process must fit the emulsion.

If small droplets of water are to be coalesced it is necessary that the surface tension of their binding sheath be reduced to such point that the water droplets may break out by gravity. Since surface tension is in direct relationship to viscosity, it is obvious that to effect good salt removal the viscosity of the crude must be lowered to such a point that droplets of water are no longer restrained by their binders. In the case of water and crude, if the viscosity is reduced by temperature, a greater difference in specific gravity will exist between the oil and brine, thus allowing a quicker and better separation.

If droplets of water can be made to contact each other, thus forming larger droplets, gravitational separation is greatly accelerated. Turbulent flow is conducive to desired contact. Furthermore the presence of baffles, grit and chat make for more contact. Often, if emulsions are difficult to break, small quantities of demulsifying chemicals may be used.

Salt removal is subject to several variables, some of which are extremely important while others seem to be of little consequence. In every case however, it is deemed advisable that all variables be watched, recorded, and correlated. It is important that the operators are educated to the variables and be kept abreast of all significant correlations.

Pressure Drop

Pressure drop is probably the most critical of all variables. A back-pressure-control valve on the discharge of the crude-charge pump allows a constant pressure drop to be maintained. Previous to the installation of the control valve, a gate valve on the discharge of the crude pump was kept in a throttled position to maintain the necessary back pressure. Various pressure drops have been tried on our composite crude ranging from 0 to 100 pounds. With minimum pressure drop salt removal is poor, ranging from 60 to 80 percent removal. Forty to 50 pounds differential across the emulsifying valve seems to be ideal for our crude. Pressure drop in the region of 75 to 100 pounds will often cause too tight an emulsion which, although often accompanied by excellent salt removal, is just as often subject to rather high water carryover (1 percent and greater).

Once the optimum pressure drop is found, small variations do not seem critical as can be readily evidenced by the fact that we use a reciprocating charge pump rather than a centrifugal pump.

Pressure drop vs. salt content of final crude, with other conditions unchanged, showed a very good correlation in the region of 0-60 pounds pressure differential.

Pressure drop vs. salt content of final crude (Figure 2) and pressure drop vs. percent salt removal (Figure 3) with other conditions varying, were correlatable.

Table 1 shows normal pressure measurements taken progressively through the salt-removal equipment.

TABLE 1

	Pressure Psig
Crude oil pump	210
Exchanger inlet	159
Baffle inlet	150
Baffle outlet	145
Vertical settler inlet	143
Horizontal settler outlet	140
Pressure outlet of residue to crude exchangers	133

The back pressure held on the system appears to be sufficiently high to prevent vaporization.

In order to get a feel of the pressures required, a small bomb was prepared and equipped with thermometer well and pressure-gauge connection. The bomb was charged with a composite crude containing approximately 10 percent water in emulsion. The mixture was heated to 280° F. and pressures and temperatures were recorded as the sample cooled. At 270° F. the apparent vapor pressure of the sample was 50 pounds. (Figure 5.)

Temperature and Viscosity

Temperature, as previously discussed, must be high enough to reduce the surface tension of the oil to the point that water will break out. Assuming that surface tension is a direct function of viscosities, temperature-viscosity curves of each of our crudes have been plotted and projected. (Figure 4.) It appears from this data that a viscosity (Saybolt Uni-

versal) of approximately 40 seconds or less on our crudes must be reached to obtain optimum salt removal.

Previous to a recent heat-exchanger revamp, the temperature of the vertical settler was approximately 130° F. These conditions afforded salt removal only in the order of 50 to 80 percent, depending upon the type of crude charged and the amount of salt in the crude, i.e. with these conditions, the greater amount of salt in the crude charge, the better the percent salt removal. Considerable amount of chemical was also used in an attempt to effect an emulsion break. The viscosity of our crude at 130° F. was 50 seconds and above.

Following the heat-exchanger revamp, the temperature of the vertical settler varies between 190 and 220° F., depending upon the quantity and temperature of topped crude exchanging heat with the crude.

At 220° F. and with an average crude charge, the viscosity is 34 seconds. With the aforementioned pressure drop of 40 to 50 pounds, water flow of 5 to 15 liquid volume percent of crude charge, and viscosity of 34 seconds, 90-95 percent salt removal may be obtained day in and day out without any chemical addition.

The importance of maintaining low viscosity has been illustrated by operating at the above conditions and suddenly changing the charge stock to a 26.3 API gravity Woodbine crude, which with approximately the same temperature in the vertical settler increases the effective viscosity to 50 seconds. The effect is as one would forecast, an increased water carryover and reduced salt removal. If, however, demulsifying chemical is added uring the charging of the heavy crude, substantially good salt removal is still obtained. For this reason a small quantity of chemical is used as a safeguard against slugs of heavy crude or tank bottoms. It is planned to provide a system whereby segregated crude stocks cannot be charged directly to the stills, but must be blended with the composite crudes.

Temperatures required for the vertical settler should be in the range of 200-250° F. There seems to be no gain in exceeding 250° F., since viscosity curves for the crude processed tend to flatten out in this range.

At present vertical settler temperatures, no difficulty has been experienced with oil entrainment in the effluent brine. However, before the recent heat-exchanger revamp, some oil entrainment in the brine was intermittently encountered.

Water Addition and Brine Concentration

Quantity of water required for emulsifying the crude does not seem to be too critical. It appears that a minimum of 5 percent by volume fresh-water injection should be used, but no maximum has been found other than limitations that might be found in added heat-transfer duty due to the presence of additional water. As high as 15 percent fresh-water charge has been used. However it must be pointed out that in a water-wash system such as the one outlined, a water level must be maintained. Since the salt concentration of the water level for a given water-flow rate will vary with the salt concentration of the crude, it becomes important to check the water-wash salt concentration and control the quantity of water charged accordingly.

It has been found that a concentration of 500 to 1000 pounds of NaCl per 1000 barrels of water is ideal, not particularly from a washing-efficiency standpoint but as a safety factor, since a loss of temperature, exceedingly high pressure drop across the emulsification valve, or some unforeseen factor might cause a carry over of a quantity of this concentrated salt water. However, if one disregards safety factors, it is known from our data that salt concentrations on the order of 1500 to 2500 pounds per 1000 barrels of water give a satisfactory water-wash.

It is claimed by some refiners that a brine concentration of 2000 to 4000 pounds of salt per 1000 barrels of water is optimum. To expect improved salt removal from the more concentrated brine is quite logical since a greater differential in specific gravities exists between the salt solution and the crude. It is also claimed that stronger brines contain higher concentrations of those demulsifiers which occur naturally in the crude. However, no reasonable correlation could be obtained that would show the advantage of one brine concentration over another.

Obviously with refineries where water is expensive enough to become a definite factor, salt concentration should be regulated for minimum water consumption.

The quality of the water we use might be questionable to some. The source of water is a hot well, which at times has a rather high dissolved and suspended solids concentration. (Tables 2 and 3.)

TABLE 2
Analysis of Water from Hot Well

	Grains per Gallon
PH equals 8.0	....
Total hardness equals	5.0
Chlorides	4.2
P	.0
M	7.0
Suspended solids	0.4
Dissolved solids	14.1
Total solids	14.5

TABLE 3
Analysis of Water from Vertical Settler

	Pounds per 1000 Bbls.	Weight Percent
CaC12	192	19.5
MgC12	162	16.4
NaC1	634	64.1
	988	100.0
PH equals		7.9

7.6 grains per gallon suspended solids
590 grains per gallon dissolved solids

Although the conditions of the water might be suspected as slightly errosive or corrosive, it has not shown any apparent ill effects. Should any corrosion be found in the vertical vessel at any time in the future, it is planned to install a ¾-inch ganister liner (luminite cement and ground brick ganister).

No trouble has been experienced with fouled heat exchangers as heat-transfer coefficients have remained approximately the same throughout the run. Apparently all solids are discarded with the water drawn from the vertical settler. A definite advantage however, is assumed in the contact coalescing value of suspended solids when present in the emulsions.

Solids at Water Oil Interface

Accumulation of solids at water-oil interface which might stabilize water-oil emulsion has not been encountered. However, the try lines are so situated

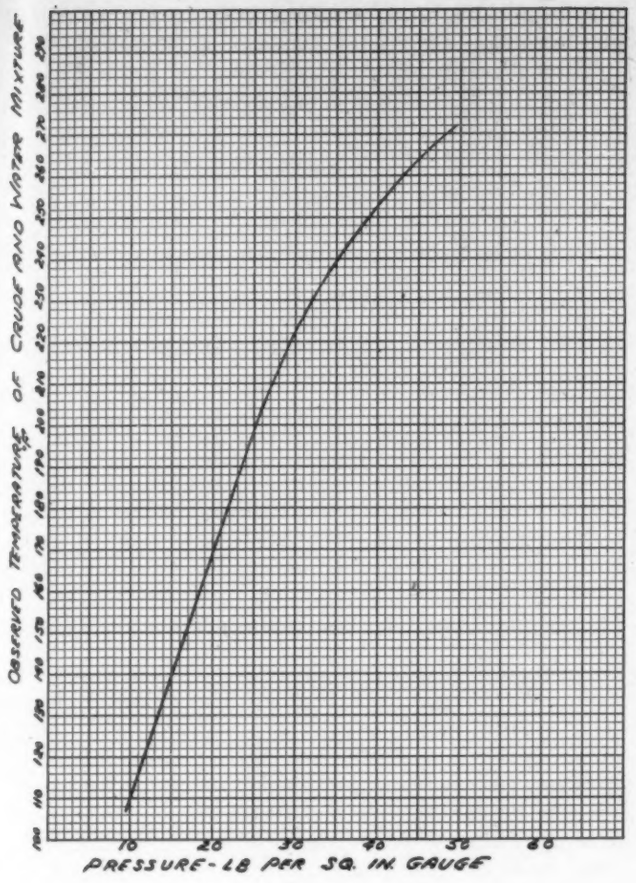


FIGURE 5

that periodic skimming of the interface would be possible if necessary.

It is doubtful if chemical is needed 95 percent of the time, but it is good insurance against slugs of heavy crude or tank bottoms. The amount of chemical currently used is approximately one quart per 500 barrels of crude charge, which represents a cost of 1.0 mill per barrel of crude.

Settling Time

It has often been asked among refiners and designers as to how much settling time is actually required for salt-removal equipment. Some simple tests carried out on the described salt-removal system may throw further light on the subject.

Since a 20-foot water level is maintained at the bottom try-cock of the vertical vessel, samples of crude are available at each of the remaining two try-cock levels, between the horizontal and the vertical settlers, and the outlet of the horizontal. BS&W is occasionally checked at each of the points to determine how quickly the emulsion break is taking place. Table 4 shows the break obtained during normal operation.

TABLE 4
Basis 3000 Barrels Daily Crude Charge Rate

	No. 1 Valve Percent	No. 2 Valve Percent	No. 3 Valve Percent	Between Settler Percent	Out of Horizontal Percent
	100 water	26	3	....	.3
	100 water	6.5	4.8	.2	.2
	100 water	100 water	8.0	.3	.2
	100 water	8.0	3.0	.2	.2
Settling time above the water level at 3000 barrels daily Charge—Minutes	0	11	22	36	117

TABLE 5

Equipment	Temperature, °F.	Residence Time, Minutes	Velocity, Feet per Second
Pump to TC, Each	70	....	....
Exchangers	70–210	3.17	4.2
Baffles	210	1.08	1.24
Vertical Settler	210	35.5	.0074
Horizontal Settler	208	81.0	.0074

From these data it appears that little settling time is required when a good break is experienced, but for cases of water carryover due to tight emulsion, the advantage of additional settling time seems doubtful. This fact was further substantiated during periods of high water carryover occurring previous to the heat-exchanger revamp as, little emulsion break was encountered beyond the vertical settler. The final settler is insurance against faulty operation, i.e. high water levels, etc.

Residence time and velocities throughout the salt-settling equipment at 3000 barrels daily crude charge are shown by Table 5.

Contact and Coalescing

The baffle section is intended to create a turbulent flow and a contact surface to coalesce so far as possible the droplets of water before they reach the vertical settler. Also, if any salt still remains coated with a paraffin sheath, the additional contact in this hot section tends to break down final resistance before entering the vertical settler.

If the baffle had not been satisfactory, it was planned to use a grit or chat as a coalescing medium in the lower section of the vertical.

An ostensible need for the additional contact section was indicated by a microscopic study of raw

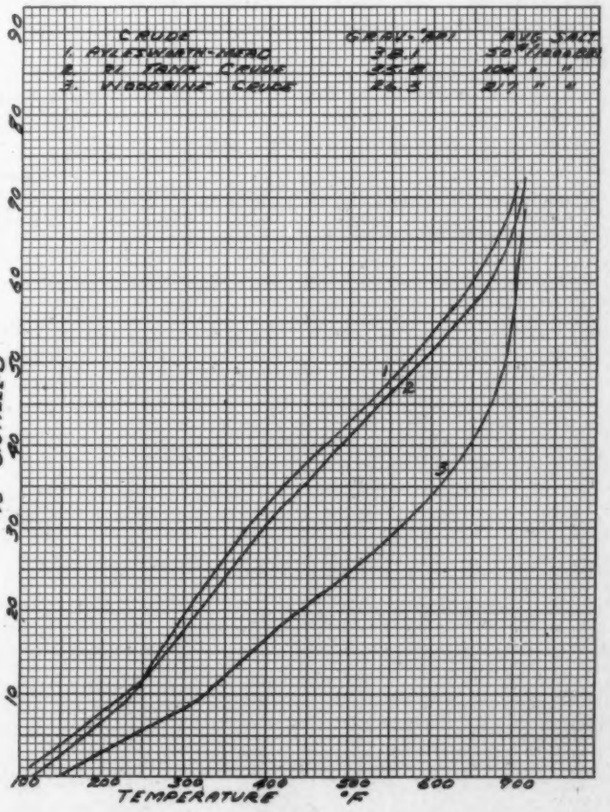


FIGURE 6
ASTM distillations of various Ben Franklin crude oil charges.

and washed crude made previous to the addition of the baffle section.

The raw crude showed three different types of crystals; one with definite angular plane surfaces another in the form of small threads, and a third type which appeared as a black shapeless mass. Crystals with angular plane surfaces were of various sizes and represented approximately 75 percent of the total crystallized material. The thread-type material constituted approximately 20 percent of the total, and the remaining 5 percent were the black masses of shapeless substances.

Examination of crystals in the washed crude showed only the smallest of the angular plane crystals remaining plus all crystals of the other types.

Crystals of the second and third class were not positively identified as salt crystals since they may have been a form of basic sediment, but it was reasonably concluded that the remaining minute angular crystals were salt.

From these data it seemed that further contact of water with the crystals was necessary after the wax film had been broken with heat.

Obviously the baffle has been beneficial in this capacity since at no time previous to its installation could the salt content of the crude be constantly reduced to as low levels as is currently being accomplished. However, other factors were probably equally important.

A representative months crude run is shown in Table 7.

ASTM distillations of various crude charges are shown by Figure 5.

U.O.P. K (characterization factor) estimated from gravity-viscosity correlations vary from 11.9 to 12.2 for various crude charges. This indicated crudes predominantly paraffinic in nature.

A composite crude evaluated by Bureau of Mines method also showed the crude to be paraffinic.

Typical operating data is shown by Table 6.

From the data and observations made of operation of crude charges, the following points should be emphasized.

TABLE 7

Gravity °API	Crude	LV%
30	Healdton	28
32	Oscar	
41	Joliff	7
36	Aylesworth	30
36	Mead	7
26	Woodbine	28

Average gravity of month's charge equals 32.0 API.

Best emulsification is obtained with 40- to 50-pound pressure drop across the emulsifying valve.

Temperature within the vertical settler must be maintained for desired emulsion-breaking viscosities (200-220° F.).

Pressure should be sufficient to prevent vaporization (130-150 psig).

Additional contact of water and crude should be induced after the crude viscosity has been reduced.

Water should be adequately metered to maintain a constant fresh-water charge for a reasonable brine concentration within the vertical settler. (5-15 liquid volume percent of crude charge.)

If chemical is used, adequate control and correlation should be utilized to minimize expenditure and obtain optimum results.

Operators must be made a part of this salt-removal program by making all correlations available to them and emphasizing the monetary value of a salt-free product.

Typical Operating Data

(December-January operation)

Temp. Vert. Settler	Pressure Drop	Water LV% of Crude	Water LV% of Carryover	Brine Concentration Lb./NaCl /1000 Bbl.	Crude Charge B/D	Salt in Lb./NaCl /1000 Bbls.	Salt Out Lb./NaCl /1000 Bbls.	Percent Removal	Chemical Used Quarts/Day	Chemical Cost/Bbl. Crude Cents/Bbl.
210	40	5.0	0.4	....	2885	88	9	90	2	.037
200	35	7.0	0.2	570	2534	65	10	85	13	.275
200	35	8.5	0.2	1500	2550	125	13	89	6	.126
200	35	8.5	0.2	....	2548	121	7	95	12	.253
200	35	11.2	0.1	....	2526	120	7	94	12	.256
210	50	11.2	0.7	908	2441	124	6	95	10	.221
190	50	10.0	0.2	....	2445	109	13	88	9	.198
195	50	10.0	0.4	796	2754	121	9	93	6	.117
195	40	10.0	0.4	....	2721	124	14	89	9	.178
200	45	12.0	0.4	936	2730	180	13	93	11	.216
185	40	7.0	0.4	584	2177	101	13	87	8	.198
200	35	6.2	0.2	....	2500	77	10	87	8	.172
210	35	8.0	0.1	....	2821	105	10	90	8	.153
195	35	6.0	0.2	....	2232	120	9	93	0	0
210	35	6.0	0.2	....	3053	115	11	94	8	.140
200	40	6.0	0.2	....	3132	163	15	91	10	.171
200	45	6.0	0.2	....	3100	135	11	91	10	.176
220	50	9.0	0.2	....	3089	117	11	91	11	.190
200	80	9.0	0.3	1563	1983	85	10	88	3	.081
200	80[1]	7.0	0.8	....	3601	85	35[1]	59[1]	2	.036
210	75	6.0	0.4	1560	2500	85	10	88	2	.043
210	10–15[2]	12.0	0.2	1572	2500	87	35[2]	60[2]	2	.043
205	50	13.0	0.2	....	2226	80	6	93	8	.193
210	50	12.0	0.2	1160	2000	60	6	90	9	.255
215	20[3]	10.0	0.1	2236	2000	88	18[3]	80[3]	8	.215
205	40	12.0	0.2	2092	3273	253	26	90	6	.098
200	40	12.0	0.2	724	3200	69	5	93	6	.101
205	45	12.0	0.2	700	2809	81	4	95	6	.114
210	45	13.0	0.2	700	2758	80	2	98	6	.117
200	50	12.0	0.2	400	3014	85	3	96	6	.107
205	50	13.0	0.1	420	3014	80	2	98	6	.107
200	50	13.0	0.2	444	2586	87	7	92	5	.104
210	50	13.0	0.1	....	2739	60	2	97	6	.118
205	50	13.0	0.1	....	2700	55	2	97	5	.100
200	50	13.0	0.1	564	2564	50	2	96	5	.105
205	50	12.0	0.2	450	2174	65	3	95	5	.124
200	50	12.0	0.1	500	1977	48	3	94	5	.136
205	50	11.0	0.2	460	1990	76	2	97	5	.136

[1] Pressure drop too high, poor emulsion break. [2] Pressure drop too low, failure of back pressure valve. [3] Pressure drop too low.

Control of Fractionation Columns

DAVID M. BOYD, JR., Monsanto Chemical Company

IT would be impossible to give a control system that would be a panacea for all fractionation-control problems, but this discussion should serve to point out some of the general principals involved. The main point to remember in applying controls to any system is to analyze the system involved and then choose controls that can handle the job. With this step handled properly, the rest of the problem will be purely mechanical.

THE problem of controlling a fractionation column is essentially one of maintaining a material balance. There is just so much material charged to the column and it either has to go overhead or out the bottom. If some of the heavy material goes out the top, the overhead product will be off specifications. Conversely, if the light ends go out the bottom, the bottoms product will be off specifications.

Methods of maintaining this material balance will depend upon the type of fractionation being accomplished in the equipment. Basically, there are two types of fractionation-control problems—continuous and batch columns. In the continuous column the material balance is maintained by controlling the heat-input to the column, while in the batch column the heat-input remains constant and the product draw-off rate is changed to allow the components of the material charged to still to come out at the required rate of purity.

Continuous Fractionation Columns

Most of the continuous fractionation-column-control systems can be separated into one of the following three types:

Type 1—Stripping-section temperature control.

Type 2—Rectification-section temperature control.

Type 3—Material-balance control.

Most of the common fractionation problems can be handled with one of the above types of control systems. Only one of the above types will give optimum results on a given fractionation problem. It is, therefore, desirable to check through the operation of each of the above types of control to see how each operates and to which type of fractionation problem it is best suited.

Type 1—Stripping-Section Temperature Control

In checking through the operation of a continuous-fractionation column, it is easy to see that, with a feed rate of constant quality and constant quantity, it would be possible to control the operation of a column by setting the flow of heat to the reboiler, and then setting the flow of products from the top and bottom of the tower.

Unfortunately, a feed rate of constant quality and quantity, day in and day out, does not occur other than in text books, and it becomes necessary to devise instrumentation to compensate for these changes in feed.

We have seen that a change of flow of heat to the reboiler will determine the amount of top and bottom make and consequently the quality of either. It is, therefore, desirable to have the control of heat to the column to be the major control function and the rest of the instrumentation designed to follow the actions of this controller or to make its job easier.

The flow of heat to the reboiler has to be modulated in order to maintain a constant quality of the material in equilibrium at some point in the column. Therefore, in order to control the flow of this heat, it becomes necessary to have a measure of the quality or composition of the material at the point under control. The usual method of determining this quality is to measure the temperature of its boiling point and then use this to control the flow of heat to the reboiler. This usually is done by means of a recording temperature controller setting the flow of steam to the reboiler.

In setting the temperature of the equilibrium conditions at one tray in the column, you automatically fix the composition or equilibrium conditions of any tray up or down the column from the tray under control, for any condition of feed. It is desirable to pick a control point where the temperature change is greatest in going from one tray to the next. It is also desirable to select this point as close as possible to the reboiler in order to not introduce too great a time-lag in the control system. The selection of the control point resolves itself into a compromise between the point of the greatest temperature change and the point with the least time-lag. For this reason it is best to provide a thermowell every third tray so that the optimum control point can be located after the column is in operation.

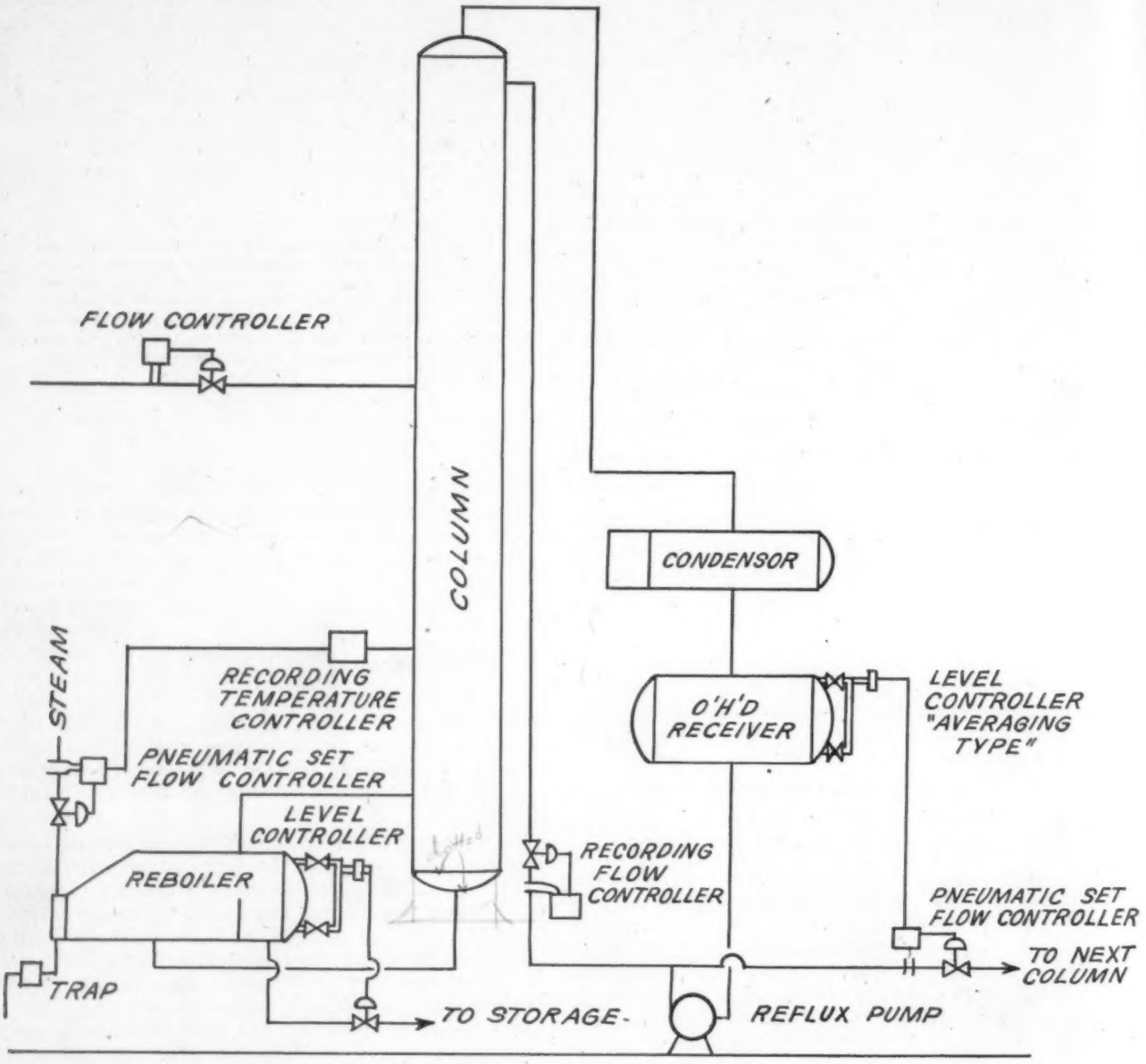
With the heat flow under control, a change in feed quality or quantity will change the quantity of overhead make and bottoms make. They will be of substantially constant quality because of the action of the column.

The flow of overhead and bottom products is controlled by level controllers. When the products are going to storage, the level controller merely opens and closes a valve as the level rises and falls. However, when the product is feeding a succeeding column, it becomes necessary to keep the feed rate to the column as constant as possible so as not to upset

its operation. In this type of operation it is best to use a flow controller with its control point reset by an "averaging" type of level controller. An "averaging" type level controller is a level controller that tries to maintain a constant flow out of a vessel by letting the level change over wide limits, thus absorbing any sudden surges and not passing them on to the next tower. The flow controller is used to maintain the flow as nearly constant as possible, irrespective of any changes in pump pressures, line losses, tower pressures, pressure drop, etc.

The reflux is maintained at a constant rate by means of a flow controller, irrespective of the column throughput. The amount set is enough to give the required reflux ratio at the largest expected throughput. At any lower throughputs, the fractionation will be improved over the design requirements. This will not hurt the product, in fact it gives a better product at lower throughputs than required.

The reason for maintaining a constant reflux rate is to ease the job of the temperature controller of the reboiler. At a 4-1 reflux ratio, 80 percent of the heat load is from the reflux. By maintaining a constant reflux rate, a 5 percent change in the feed rate would only require a 1 percent change in the steam-input to the reboiler, thus reducing the changes required of the temperature controller. It must be remembered that the temperature controller is a very slow acting instrument and control system. There are several time-lags, such as the time-lags in the thermowell, measuring system, control system, and the heat-transfer time-lags in the reboiler and at each plate, that all add up to give an unfavorable control characteristic as compared to the control of pressure and flow. Consequently, everything possible should be done to reduce the changes that the temperature controller has to make. An example of this is the use of a pneumatic-set flow controller on the steam to the reboiler. This instrument keeps a constant flow of heat into the reboiler irrespective of any changes in



Stripping Section Temperature-Control System.

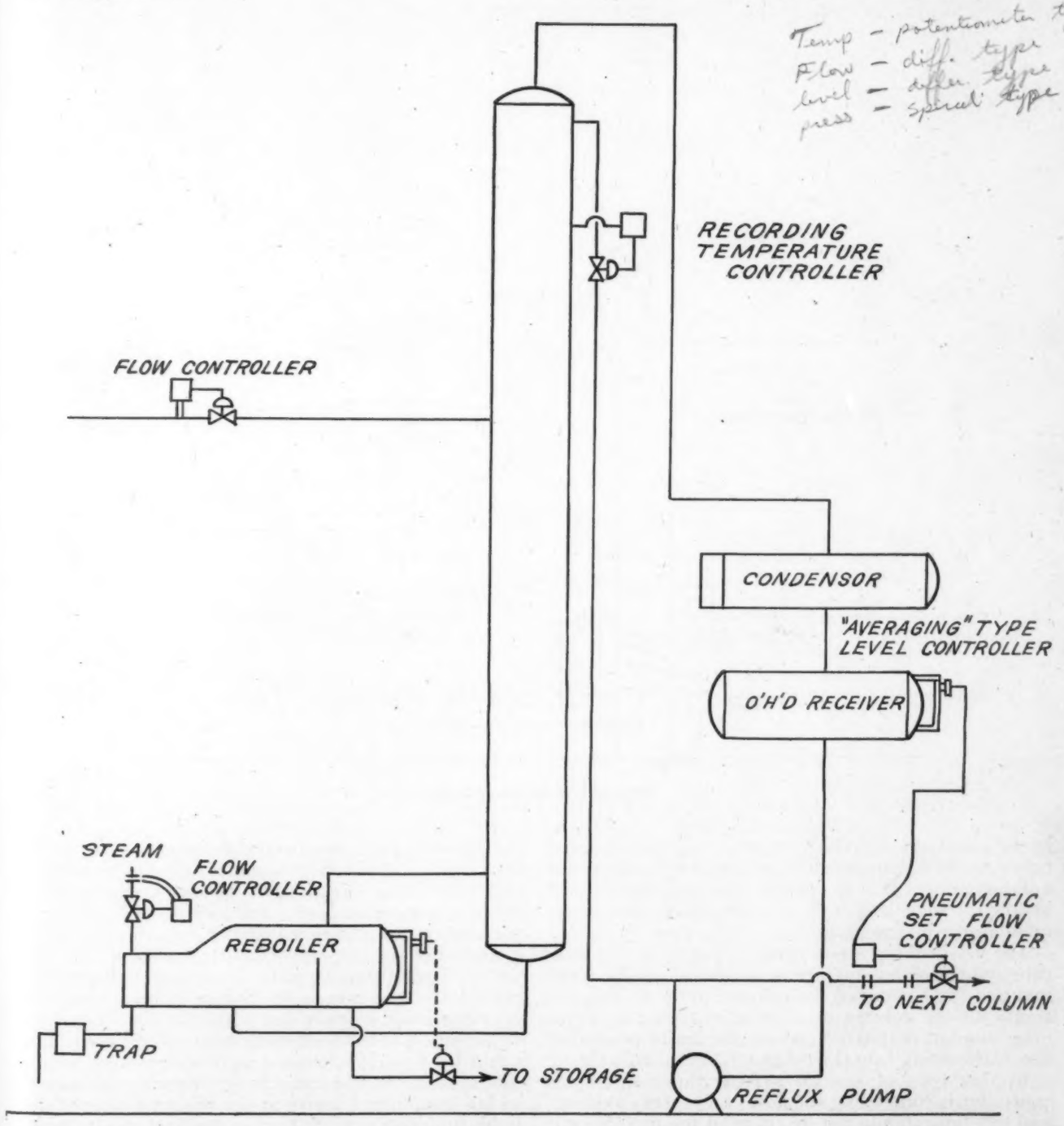
steam-header pressures, line losses, heat-transfer coefficients, etc. This instrument corrects for these upsets before they reach the temperature controller, thus reducing the work required of it.

With the mentioned control equipment, it should be possible to handle a large percentage of the fractionation-control problems. However, it must be remembered that for optimum control with this system, the thermocouple must be located near the reboiler, in order to reduce the time-lag in the control system. In other words, it must be located below the feed plate or in the stripping section of the column. Quite often a large plate-to-plate temperature gradient is not found in the stripping section of the column and, therefore, this type of control system is not applicable.

Type 2—Rectification-Section Temperature Control

If, for some reason, it is not possible to use a stripping-section temperature control and a satisfactory temperature gradient is located above the feed plate of the column or in the rectification section of the column, it is desirable to use the rectification-section temperature-control system. This system controls the material balance of the column by controlling the amount of reflux returned to the column by means of a temperature controller.

There is a fixed amount of heat coming into the column through the flow controller on the steam to the reboiler. This will make a certain amount of overhead product for a given amount of feed and reflux. By changing the amount of reflux we can change the amount of product made, because for a



Rectification Section Temperature Control.

given amount of heat into the column through the reboiler there will be a definite amount of distillate made. This distillate can be returned to the column as reflux or sent from the column as product. Because of the action of the column, the quality of the product made will depend upon the amount that is made. The composition of the overhead product will determine the position of the composition gradient within the column.

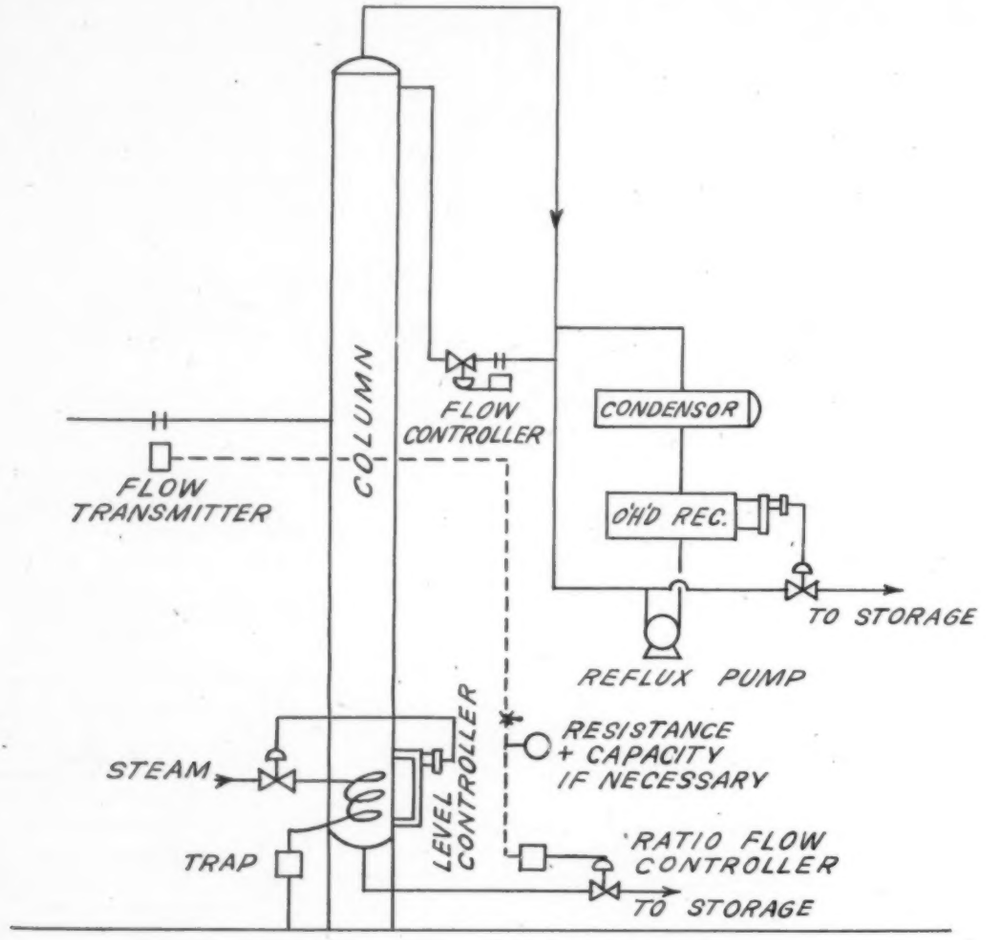
In operating a column of this type, enough steam is flowed to the reboiler to cause the temperature controller to give the required reflux ratio at the maximum rate of feed. As in the first type of control system, this system will give a higher reflux ratio at the lower rates of feed, but this only gives a little purer product than required and does not amount to a disadvantage. If it is known that the feed rate will be low for some length of time, the steam flow to the reboiler can be cut back.

The use of this type of control system is also indicated when there is no means of controlling the heat-input to the bottom of the column, as in an installation with the column on the outlet of a reactor or other similar installation, where the major portion of the heat coming into the column is uncontrollable.

In this type of control system the temperature controller is controlling the flow of a process medium, and this flow should not be changed too rapidly or it would be very possible to flood the column. For this reason the use of a derivative type of controller should be avoided. Even though this type of control would give excellent control of the temperature, it still might not give a good product due to the flooding of the column in the upper plates.

Type 3—Material-Balance Control

The first two types of control systems required a temperature change in order for their controls to function. This temperature change was a result of a change in composition. Any other method of measuring the change in composition could be used as the controlling function in either Type 1 or Type 2 control systems, provided the time-lag in the measuring system was not excessive.



Material Balance Control System.

However, when temperature control or any other type of composition measurement cannot be used as the controlling function, it becomes necessary to devise other methods of column control.

In most fractionation installations, the quality or composition of the feed is fairly constant and will probably not change greatly from hour to hour, even though the feed rate might change quite a little. The operator could be provided with an indication of the composition of the feed every hour or half hour. This could be done by chemical analysis or other means. The operator would then change the material balance of his column and arrive at the required composition in his final products. Naturally, the final results would not be as good as if he had a continuous measurement

of the composition of the material at some point in the system.

Such a material-balance control system would consist of a ratio flow controller on the bottoms product, that was reset by the changes in the feed-flow rate. The amount that the bottoms product changed would depend, therefore, upon the change in the feed-flow rate and the ratio setting on the ratio controller. The rate at which it should change will depend largely upon the time-lag in the column. If this time-lag is excessive, it might be necessary to install a restriction and capacity in the line from the flow transmitter in order to match the time-lag in the column.

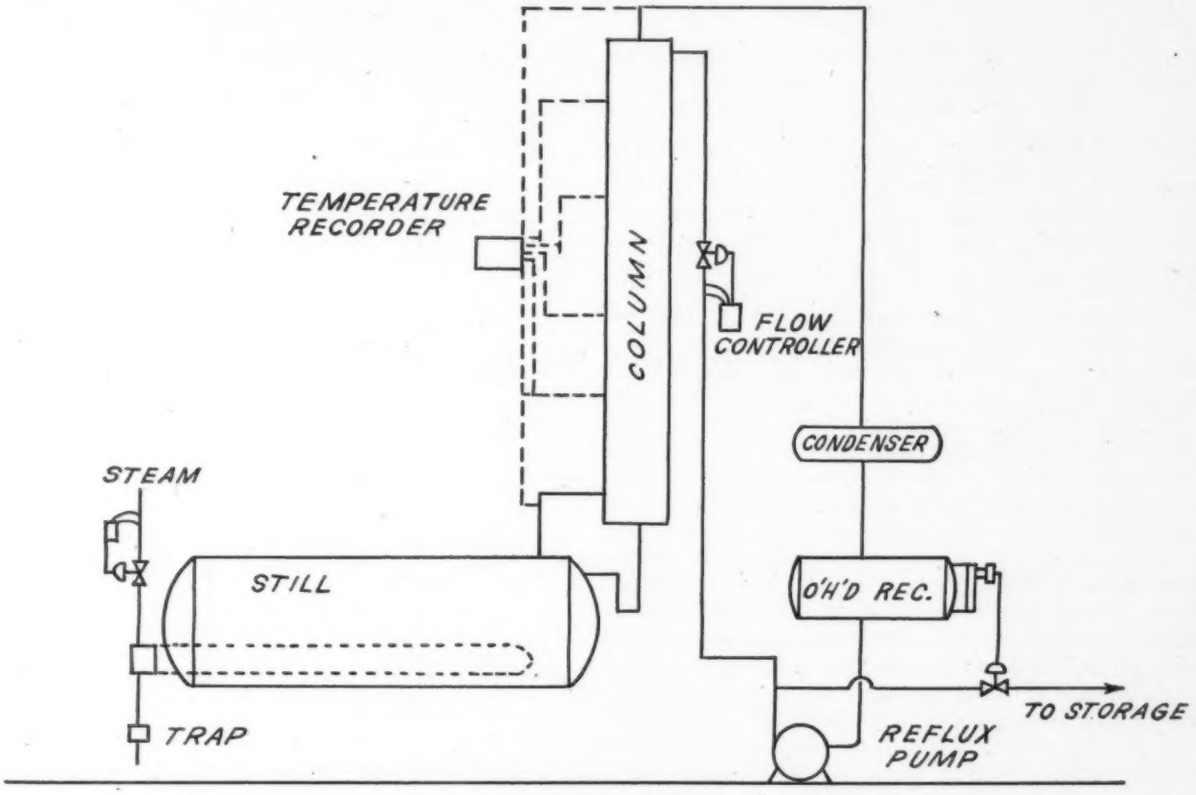
A level controller on the column bottom controls the steam to the reboiler and flashes overhead everything that the ratio controller does not take out the bottom. This level controller should be provided with a wide throttling range, in order to prevent surging in the control system.

The reflux to the column is on flow control and should be set to give the required reflux ratio at the maximum throughput. The level controller on the overhead surge drum controls the overhead make as in the other two types of control systems.

The design of the fractionation equipment using this type of control system should be very conservative. There should be an extra number of plates in the column in order to minimize the changes in feed composition. The feed drum for this column should be large enough to allow the composition changes to balance out as much as possible before being charged to the column. Use of this type of control system is recommended only when Types 1 and 2 cannot be used. Temperature control of fractionation columns is not too successful below an 8-10° F. spread in boiling range of the components.

Batch-Fractionation Columns

Control of a batch column is essentially a problem of keeping the column operating at its highest efficiency and controlling the amount of reflux returned to the column. The problem of control on a batch column is entirely different from that of a continuous column. In a continuous column you try to maintain constant composition in the top and bottom products, while in the batch still you have several overhead products depending upon the original charge to the still. As the "cut point" approaches on one of the products, it becomes necessary to keep increasing the reflux ratio in order to rectify out the last of the first cut so that it will not be contaminated and also that it will not contaminate the following cut. Operation of such a column is stepwise with the overhead temperature dependent upon the cut that is being removed at that time.



Batch-Fractionation Column.

Instrumentation of a batch column would require a flow controller on the steam to the reboiler, a flow controller on the reflux, and a multiple-point temperature recorder with thermocouples located at different points up the column. The operator can watch the temperature recorder to see when his "cut point" is approaching and consequently when to increase his reflux ratio.

Certain types of automatic laboratory columns use an automatic temperature controller that will increase the reflux ratio whenever the temperature in the overhead starts to rise no matter what the temperature is at the time. An instrument similar to this might be adapted to a batch-fractionating column to give automatic control of the reflux rate. This refinement probably would not be necessary in most of the batch-fractionating columns as these columns do not require as elaborate a control system as the continuous-fractionation systems require.

Basic Petroleum Chemistry For Refinery Employes

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Chapter II

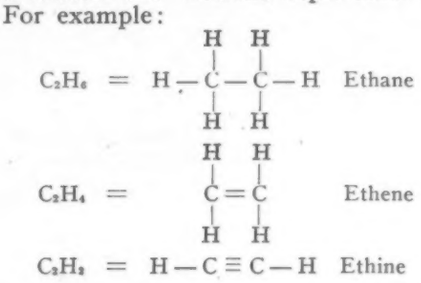
NAMING HYDROCARBONS

IT IS desirable that the name of any hydrocarbon compound should indicate its structure, but unfortunately quite a number of hydrocarbon compounds were named long before their structures were known, and, because of their established usage, the original names have survived. The more common of these early-named hydrocarbons are methane, ethane, propane, and butane. Some of the important properties are tabulated below in Table 1. Properties of other important hydrocarbons are shown in Table 3.

When the above four compounds or groups become a part of a larger molecule, they are called methyl, ethyl, propyl and butyl radicals respectively.

In 1893 a congress of chemists met in Geneva to agree upon a system of naming organic (hydrocarbon) compounds. They devised a system which would describe the structure of the compounds accurately. The existing names for the first four members of the normal hydrocarbon series were not changed, but the higher members of the series were given names which were derived from Greek numbers, pentane, hexane, heptane, octane, nonane, decane, etc.

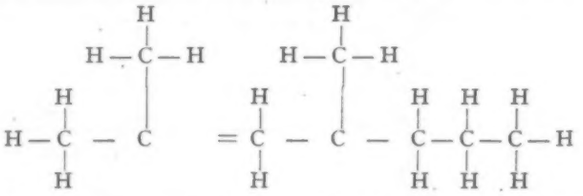
It will be observed that all of the saturated series of hydrocarbons end in the letters "ane." These are called normal saturated hydrocarbons. In order to differentiate between the saturated and unsaturated series, the congress agreed to end the spelling of the members of the double bond or unsaturated series with the letters "ene" and the triple bond series with "ine." For example:



Ethine is also known by the name "Ethyne" and more commonly as "Acetylene."

By this system a hydrocarbon is named as a derivative of the normal hydrocarbon which corresponds to the longest continuous chain in the formula.

Let us, for example, give a name to the hydrocarbon which has the following structural formula:



There are seven carbon atoms in the longest con-

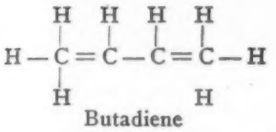
TABLE 1

Molecular Formulae	Structural Formulae	Name	Molecular Weight	°F. Boiling Point	PSI @ 100° F. Vapor Pressure	Octane Number
CH_4		Methane	16.042	—258°	8,000	110 M*
C_2H_6		Ethane	30.068	—128°	800	104 M
C_3H_8		Propane	44.094	—44°	187	100 M
C_4H_{10}		Butane	58.120	+31°	52.5	92 M

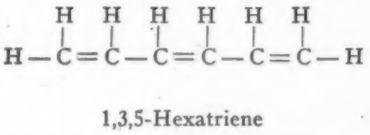
* M After an octane number indicates value determined by Motor Method. R Indicates Research Method.

tinuous chain. Our first thought is to call the compound a heptane. However, we notice that there is a double bond between the second and third carbon atom. It is an unsaturated compound which requires the ending "ene." Since there are attached two methyl groups, we could name the compound dimethyl heptene. That would be only partially correct, because the name dimethyl heptene does not indicate to what carbon atoms the two methyl groups are attached, or between what two carbon atoms the double bond occurs. In order to indicate that the double bond is between the second and third carbon in the heptene chain, we place the numeral 2 before heptene, 2-heptene. The carbons in a hydrocarbon chain may be numbered starting from either the right or left end, but established practice requires that we number from the end which would employ the smaller number to indicate the position of attached side chains. In case of the compound represented above, therefore, it could be named (right to left) 4-6 dimethyl 5-heptene, or (left to right) 2-4 dimethyl 2-heptene. The latter is the proper name since it makes use of the smaller numbers.

A molecule having two and three double bonds in their structures are given names ending in *di*ene and *tri*ene. For example:

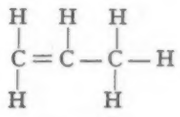


Butadiene

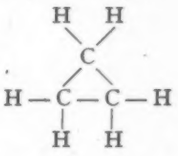


1,3,5-Hexatriene

It is possible to construct two structural formulæ having molecular formulae C_3H_6. For example:



and



Propene

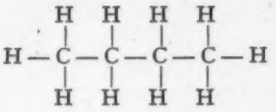
*Cyclo*propane

Molecular Weight = 42.079 42.079
Boiling Point = —54° F. —27.2° F.

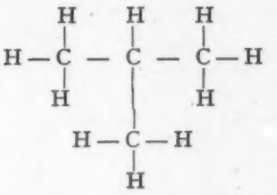
Although the molecular formulae of these two compounds are the same, their physical and chemical properties are quite different. Many of the straight-chain hydrocarbons can be converted to cyclo compounds which have highly specialized uses. Some of these compounds will be considered specifically in a later chapter.

Knowing that hydrogen has a valence of one and carbon has a valence of four, we can see that it is possible to construct, on paper at least, two molecules which have the formula C_4H_{10}.

(1)



(2)



Actually, there are two such compounds having very distinct and different chemical and physical properties. As you know, the first is called normal butane and the second 2-methyl propane—more commonly called isobutane. Such compounds which have the same molecular formula but different structure are known as "isomers." There are three known compounds having the formula C_5H_{12}—pentanes, five with the formula C_6H_{14}—hexanes, nine with the formula C_7H_{16}— heptanes, and the number of possible isomers increases rapidly as the number of carbons in the compounds increase. For instance, a compound having 20 carbon atoms in its molecule could have 366,319 possible isomers while a compound with 40 carbons could have 62,491,178,805,831 possible isomers.

There is another group of compounds which are derivatives of benzene and are called aromatic hydrocarbons. Like the cyclo compounds, the carbons in aromatic compounds form a closed ring. See Table 2.

The aromatic compounds also include two-ring

TABLE 2

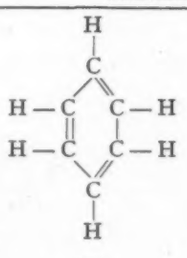
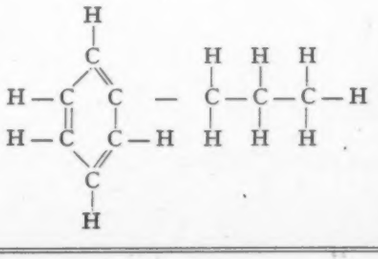
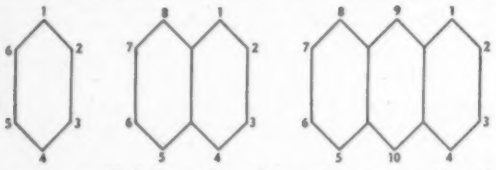
Molecular Formulae	Structural Formulae	Name	Molecular Weight	°F. Boiling Point	PSI @ 100° F. Vapor Pressure	Octane Number
C_6H_6		Benzene	78.108	176.2°	3.2	100+R
C_9H_{12}		Propyl Benzene	121.186	319.1°	1	99M

TABLE 3

	Molecular Formulae	Molecular Weight	Specific Gravity Liquid 60/60	Specific Gravity Vapor to Air	°F. Boiling Point	Inflammability Limit		Heat of Combustion BTU/Pound Vapor		Octane Number
						Low % in Air	High % in Air	Gross	Net	
Ethene	C_2H_4	28.052	0.5699 at—104c	0.9852	—155	2.75	28.60	21,650	20,300	81M
Propene	C_3H_6	42.078	0.6095 at—48c	1.469	— 53.7	2.00	11.10	21,060	19,700	85M
Butene-1	C_4H_8	56.104	0.625 at—6c	1.96	21	1.70	9.00	20,860	19,500	80M
2-Methylpropane (Isobutane)	C_4H_{10}	58.120	0.5572 20/4*	2.006	13.5	1.80	8.44	21,290	19,650	99M
2-Methylpropene (Isobutene)	C_4H_8	56.104	0.6268 at—6c	2.011	20	....	....	20,740	19,380	87M
Pentane	C_5H_{12}	72.146	0.6262 20/4	2.491	97	1.40	7.80	21,120	19,540	64M
2-Methylbutane (Isopentane)	C_5H_{12}	72.146	0.6197 20/4	2.491	82	1.32	....	21,060	19,470	90M
Hexane	C_6H_{14}	86.172	0.6594 20/4	2.975	156	1.25	6.90	20,970	19,420	26M
Heptane	C_7H_{16}	100.198	0.6838 20/4	3.459	209	1.00	6.0	20,860	19,340	0
Octane	C_8H_{18}	114.224	0.7028 20/4	3.940	258	.95	....	20,780	19,270	—17M
2, 2, 4-Trimethylpentane (Isooctane)	C_8H_{18}	114.224	0.6920 20/4	3.944	210.7	....	....	20,560	19,060	100M
Benzene	C_6H_6	78.108	0.8789 20/4	2.77	176.2	1.41	6.75	18,225	17,490	100+M
Methylbenzine (Toulene)	C_7H_8	92.134	0.8669 20/4	3.14	232	1.27	6.75	18,470	17,640	100+M

* Hydrocarbon at 20°c, Water at r°c.

compounds called naphthalenes and three-ring compounds called anthracenes. The chemistry of these compounds and the naming of them is too complicated to consider at length in an elementary discussion such as this. However, many of the rules which apply to the naming of straight- and branched-chain hydrocarbons, also apply in the naming of isomeric derivatives of aromatics. The carbon atoms are numbered in a clockwise manner as indicated below:



There are available splendid references should the reader wish to investigate the subject of nomenclature thoroughly.[2, 3, 4, 5, 6]

The naming of compounds which contain elements other than carbon and hydrogen will be considered only briefly in future discussions on Petroleum Impurities.

With at least a superficial knowledge of fundamental chemistry and the system of naming hydrocarbons, we are ready to consider the chemical composition of crude petroleum. This will be the subject of Chapter 3.

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[4] Faust, Paul H., "What Is Chemical Notation All About?" Petroleum Refiner, March, 1943, Vol. 22, No. 3, pp. 87.

[5] Faust, Paul H., "Hydrocarbon Chemistry for the Refinery Worker" Petroleum Refiner, August, 1942, Vol. 21, No. 8, pp. 67.

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Selection, Installation and Maintenance of

Refinery Process Control Instruments

Part 2

Temperature and Pressure

EUGENE BAINBRIDGE, Cities Service Refining Company

TEMPERATURE measurement is unquestionably the most important of the instrument functions in an oil refinery. Because of the change in the physical and chemical state of petroleum products at high temperatures, it is necessary for the temperatures to check within ± 1 degree at 900°F., or within limits of ± 0.1 percent of scale range. Besides accuracy, the requirements for speed of response are much more demanding, therefore careful selection of the proper instrument should be made for each process.

As in all other types of instruments used in the refinery, a choice is possible. There are four basic types and the selection of any one of these is due to the characteristics of the instrument, or in some cases, to the individual whim of some operating group.

The simplest of these types is the pressure pyrometer. The principle involved in the construction of this group is based on Charles law which states: "The pressure of a gas at constant volume varies directly with the absolute temperature of the gas." And as the volume in the bulb and capillary of the system is maintained constant, any changes in the temperature along the sensitive bulb will increase the internal pressure, causing a movement of a pen actuating linkage, calibrated in degrees Fahrenheit, and will be an indication of the temperature at the bulb.

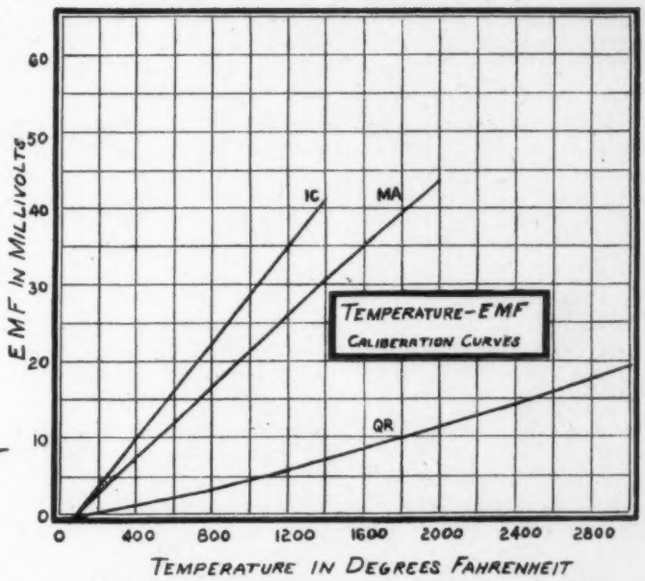
The pressure pyrometers are grouped generally in four classes. The ranges and filling mediums are given below:

Class 1 is a special type of Class 4, and is mercury-filled and used on temperatures up to and including 1200°F.

Class 2 is the vapor-filled system. It is partially filled with a volatile liquid. As the liquid is heated in the bulb, it evaporates and builds up pressure until the vapor space is saturated. As the rate of vaporization depends on the temperature, so the pressure also depends on the temperature, and this pressure can be transmitted to a pen movement calibrated in degrees. Material used as fills and the temperature range of each follows, all temperatures fahrenheit: sulphur dioxide, — 20 to 250; ether, 50 to 300; and alcohol, 150 to 400. In this type no high ranges are available.

Class 3 is usually filled with nitrogen and is used at temperature of 0 to 1000°F.

Class 4 is liquid filled, and this type is based on the fact that the coefficient of expansion of liquids



is much greater than that of a solid container. Many different liquids are used; methyl alcohol for a range of — 60 to 150; ether, 70 to 200; acetone, 110 to 230; analine, 325 to 460; zylene, — 40 to 750; and ethyl alcohol, 150 to 260. All temperatures based on the fahrenheit scale.

The advantage of the pressure thermometer is the relative low initial cost of the unit. But the initial saving is completely offset by the increased cost of maintenance wherever the capillary is subject to damage. In this case it is necessary to return the instrument to the factory for costly repairs, and to substitute other methods of measuring the temperature during these repairs. Another disadvantage of type type is its lack of flexibility. It is necessary, as a general rule, to purchase each instrument for an individual application, and when it is necessary to move the instrument the original conditions of the installation must be duplicated, sometimes at great expense. In some types, the scale or chart is unevenly graduated, making the temperature hard to read at certain points. Compensation for changes in ambient temperature is possible but is not accurate, and in most cases necessitates additional tubing. As can be seen from the ranges given above, the range of this type is restricted to a maximum of 1200°F.

The millivolt meter was more commonly used in the early years of oil processing. Where accuracy

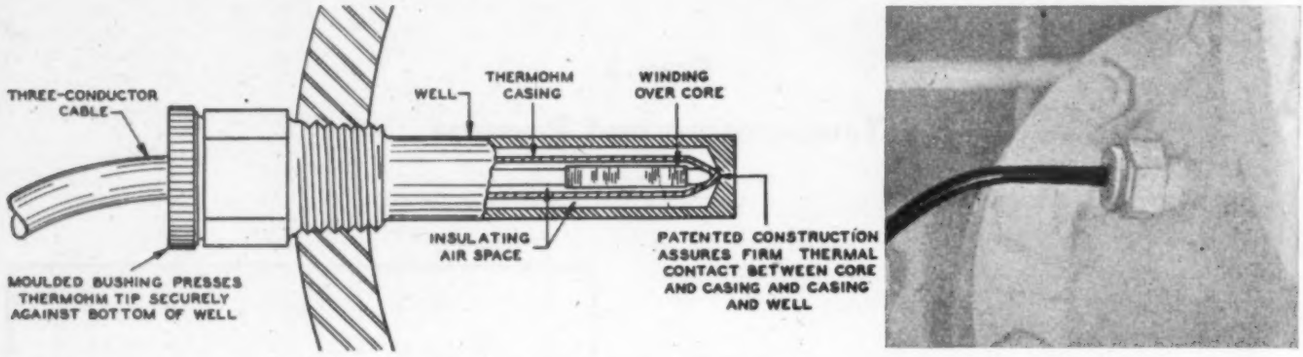
is not important and a cheap instrument is desired, it proves very satisfactory. Fundamentally it is nothing more than a volt meter and as such employs a permanent magnet and moving coil with pivots and hair springs to oppose the coils torque. The deflection of the pointer attached to this coil is proportional to the current passing through the coil and this current in turn is proportional to the electromotive force developed by the thermocouple. When the scale along which the pointer moves is calibrated in degrees, the indication is a record of the temperature of the thermocouple.

The advantages of the millivolt meter are limited to the increased number of temperature points that can be measured on one instrument and the additional ease of adapting it to other than the original installation. Accuracy of the millivolt meter depends to a great extent on the proper calibration of the instrument, and this in turn depends on the length of the lead lines as well as proper connections. The disadvantage of this type is the dependence on accurate correction for thermocouple lead-line length and the necessity of pivots being used on the galvanometer coil. When these pivots become dull or dirty, the accuracy of the meter is decreased to prohibitive limits. The millivolt meter does not lend itself to accurate cold-junction correction methods. And the gradual deterioration of the thermo couple will seriously affect its resistance and will cause a subsequent error in the temperature indication.

The most common temperature-measuring device used in oil refining is the potentiometer type of pyrometer. This is a natural choice, because, of the fundamental principles of this instrument. It differs from the millivolt meter in that no complete current flows. In principle, the electromotive force generated by the thermocouple is opposed by an electromotive force in the circuit, generated by a dry-cell battery or similar source of current. This system is called the "null" or "balance" type, as when the potential at the thermocouple and that of the battery current is at balance, no current flows and the galvanometer remains at zero position.

This type reacts very favorably to the electrical means of cold-junction correction, and very little if any effect is noticed on the temperature indication with changes of ambient temperatures. This manner of correcting for changes in ambient temperatures is based on the introduction of a nickel coil in the circuit. This coil has straight-line characteristics in reference to its ability to change resistance for a change in temperature, therefore the temperature of the thermocouple connection to the instrument does not have to be held constant.

The greatest advantage of this type over preceding types is that no correction is necessary for thermocouple lead lines. This point alone makes the potentiometer adaptable to practically all applications. It is possible to have a great number of temperature points to record on one instrument through the use of a rotary switch movement.


THREE-CONDUCTOR CABLE
WELL
THERMOHM CASING
WINDING OVER CORE
INSULATING AIR SPACE
MOULDED BUSHING PRESSES THERMOHM TIP SECURELY AGAINST BOTTOM OF WELL
PATENTED CONSTRUCTION ASSURES FIRM THERMAL CONTACT BETWEEN CORE AND CASING AND CASING AND WELL

Resistance Thermometer Bulb

The disadvantage of the potentiometer system is the necessity of maintaining the battery potential at a constant prescribed point. This is done by means of checking the potential periodically against that of a known voltage, as that of a standard cell, and then adjusting it to the desired potential. This disadvantage has been minimized by the introduction of the automatic standardizing system in the recording types.

Resistance Thermometer

The fourth type of temperature-measuring device is the resistance thermometer. This instrument finds its greatest field of application in temperatures below 300°F., and when a small span is desired. The reason for this choice is that the electromotive force generated by the thermocouple at these low temperatures is small and inaccuracies may result when it is used.

Temperature measurement by the resistance-thermometer method is based on the use of a suitable coil of wire, the electrical resistance of which is definitely related to the temperature and which maintains this relationship unchanged over a long period. This resistance or change of resistance is measured by a whetstone bridge, which balances the coil resistance against an adjustable standard resistance. A galvanometer similar to the type used in the potentiometer will indicate when a balance exists between these two resistances. The amount of resistance it is necessary to introduce into the circuit to bring about this condition will be a measure of the temperature at the bulb. Therefore, by transmitting the change of resistance of the variable to a scale calibrated in degrees, an accurate record of the temperature is obtained.

This instrument is more accurate than the other types and if the bulb is enclosed in the proper protecting device, it will normally be more sensitive. The disadvantage of this type is its relatively low temperature span, 300°F. being the usual limit. Another disadvantage is the comparative fragile coil of wire used to sense the temperature changes at the bulb. This coil is of necessity insulated by porcelain and

is subject to physical damage if not carefully handled.

Electronic Potentiometer

The introduction of the electronic potentiometer in the past few years promises to open new fields in temperature measurement and control. The use of this type has been limited because of inability of the manufacturers to supply a strip chart recorder. Most electronic types now being used in the oil industry are of the circular chart type. With the exception of the bulb or pressure thermometer type, the preceding instruments can be furnished in the strip type chart, which is a definite advantage because a continual record for a period of a month can be secured on one chart. The electronic instruments have been equipped with the 24-hour circular chart, which, besides not giving a continual record, necessitates the operator changing it at some specified time in the 24-hour period.

Although the electronic instrument makes use of the "null-balance" measuring circuit, it differs from the conventional type potentiometer because instead of a galvanometer and its associated mechanisms it makes use of a conversion stage and amplifier. When a condition of unbalance exists in the measuring circuit the electronic unit converts the unbalanced voltage and amplifies it sufficiently to operate a motor which repositions the slide wire or variable resistance contactor to the proper position to balance the circuit. As in the conventional type potentiometer, the amount of resistance necessary to introduce into the system to bring about this condition is a measure of the temperature at the thermocouple, and by the use of mechanical devices, this temperature can be transmitted to a scale calibrated in degrees. This particular type has the added advantage, that in case of thermocouple failure, the measuring circuit will be open and the balancing motor will not move. This is a decided advantage in control applications.

As in all instruments, independent of their type or classification, the selection of the proper temperature measuring device depends entirely on the application involved.

Installation

Before progressing into the installation of temperature instruments, it may be well to digress from the actual installation methods used and discuss the characteristics of the thermocouple and its attendant protecting tube.

The theory of the thermocouple evolves from the discoveries of Seebeck, Peltier and Thomson. The final result of their discoveries was that if a complete circuit of two dissimilar metals be made and the junctions be kept at different temperatures, a current will flow in the circuit. This current depended in magnitude upon the metals used and upon the actual temperature of the two junction points, and not upon the temperature difference. The use of this principle has been developed into high-temperature measurement of today.

The desirable characterists of the thermocouple can be listed as:

1. The electromotive force produced should be of ample magnitude to give a desirable range to the meter.
2. Reproductivity—it should be easy to reproduce in the field.
3. Stability of calibration—it should retain its values of electromotive force for sustained periods.
4. It should resist thermal, chemical and physical shock.
5. It should be obtainable at low cost.

Experience dictated the use of certain metal combinations for thermocouple to be used at different temperatures. The two combinations most generally used are iron-constantan and chromel-alumel. The former is made of one iron wire and the other of constantan, which consists of 45 percent copper, and 55 percent nickel. In the chromel-alumel combination, the chromel wire is 97 percent chromium and 3 percent nickel, while the alumel wire is 97 percent chromel and 3 percent aluminum. Another type, as well known but not as extensively used, is the platinum-platinum-rhodium couple, where one wire is pure platinum and the other is 13 percent rhodium and 87 percent platinum. This couple is expensive and is not generally used in the refinery with the exception of the laboratory.

Characterists of the iron-constantan couple limits its use to maximum temperatures of 1400°F. or less. But the chromel-alumel couple will serve satisfactorily at temperatures as high as 1900°F. for sustained periods. Although the iron-constantan couple maintains favorable characteristics for a longer period, it deteriorates very rapidly when deterioration begins. Chromel-alumel couple deterioration is gradual and it is necessary to pay close attention to any obvious sign the temperature indication is deviating from the true temperature point.

In most applications of pyrometers in the oil refinery it is necessary to place the temperature-sensitive element in a protecting tube. Protecting tubes are used in open kettles because of the necessity of protecting the thermocouple from oxidation, corrosion and contamination. While it is necessary to use the protecting tube in a closed vessel for the above reason, normally the tower is under pressure or it is necessary to place the thermocouple in a location that would not be accessible without the use of a protecting tube. Therefore these tubes suitable for use in high pressure service are commonly used in oil processing.

Books have been written on the characteristics of the protecting tubes necessary for each application and it is not within the scope of this article to go so far into detail. Let it suffice to say that the tube should be of a metal to resist chemically and physically any conditions that might be encountered in the process. Where a tube of unusual length is necessary, it should be placed in a vertical position, as if it is placed horizontally it may develop certain drooping characteristics.

The tube should be placed at a point of relative high fluid velocity, as a much more accurate temperature indication will be obtained. Extreme care should be used to avoid installation of the tube in any stagnant area, where the temperature would deviate from the actual operating temperatures. The relative thickness of the tube should be kept at a minimum, in keeping with the conditions prevalent in the process. The temperature-sensitive element should come in contact with the metal of the protecting tube wherever it is possible, as this will help to avoid any thermal-conductivity lags that would be present if an air space existed between this element and the protecting tube. Often individual instrument men introduce various refinements on installation of this equipment. One of these is the use

of unions at the thermocoupe to make the removal of the thermocouple from the protecting tube a more simple matter.

After the thermocouple and protecting tube is installed properly, the instrument should be installed in a level position, free from vibrations. Where excessive low-frequency vibrations occur, it will be necessary to mount the instrument on rubber or spring cushions. It is necessary in the case of high-frequency vibrations to adjust the galvanometer tension to compensate for erratic operation of the instrument.

Electricity to operate the drive motor should be installed in separate conduit and connected to the proper terminals. Care should be exercised to see that thermocouple lead lines are not installed in conduit carrying relatively higher voltage, as parasitic currents may be induced causing erratic operation of the instrument.

Wire Connections

In the care of the potentiometer, after the thermocouple and the instrument has been installed, it is necessary to connect the two by suitable lead lines. The wire is generally 14 or 16 B&S gauge rubber- or asbestos-covered wire, the choice depending on the application. Where excessive ambient temperatures are present the asbestos-covered wire should be used. Tests show that the choice between 14 and 16 wire to be somewhat of a personal choice. Thermocouple lead wire used with potentiometers has, of necessity, the same general thermal electric characteristics of the thermocouple wire with which they are used, but because of the relatively higher cost of the wire used in making thermocouples, a somewhat inferior wire is used, but it will maintain the general characteristics of the thermocouple if not subjected to temperatures in excess of 200°F. Care should be used to see that all connections are of the same polarity.

Installation of the millivolt meter will correspond in every detail to that of the potentiometer with the exception of the necessary correction for lead-line length.

Installation of the resistance thermometer involves a problem that heretofore was of little importance. Although, in the millivolt meter we compensated the instrument for lead-line length, in the resistance thermometer we must compensate for any possible change in resistance along the lead lines to the instrument from the bulb. As we are interested in the measurement of resistance the selection of the lead wire is of the greatest importance. The wire used is generally No. 14 B&S gauge copper wire of the three-conductor type and comes rubber covered and rubber insulated. The three-conductor wire is necessary to compensate for the possible variation of resistance which might occur where the instrument is at considerable distance from the temperature-sensitive bulb. When the wires are connected properly any change in resistance along the lead-line length will be compensated for by introducing the same change in each side of the bridge circuit. The current to operate the motor should be connected in the usual manner.

In the pressure thermometer, as in the preceding types of temperature-measuring instruments, the installation of the indicating instrument is of secondary importance to the installation of the bulb and capillary. As the bulb, capillary and instrument are one piece, the problem of installation is somewhat simple, but with long lengths of capillary it can become a tedious job. The bulb should be immersed in a protecting well, which has been chosen according to previously discussed standards. Usually a union connection is installed at the well to facilitate removal of the bulb when the equipment might be subjected to a temperature which might over range the instrument, causing permanent damage. The well should be placed in a location of relative high velocity, so the effects of any temperature change will be felt immediately. Some instrument departments install the tubing and protecting cable in large conduit to minimize the effects of corrosive atmospheres.

The extra care used in the installation of the temperature instrument will result in less trouble in the operation of the equipment, and the following points should be carefully watched when installing any of the above types:

1. Immersion—The test for sufficient immersion (provided there is a space for uniform temperature) is to observe that the immersion selected is enough that a little less gives the same temperature.
2. Installation of well—Insert the thermowell or protecting tube at right angles to the flow of heat or fluid.
3. Thermal-contact—Every means should be used to promote thermal contact and low resistance to heat flow between the temperature-sensitive element and the fluid.
4. Velocity—Care should be used to install the temperature-sensitive element in a location of relative high velocity and any stagnant area should be avoided.

Maintenance of Temperature-Indicating Instruments

Each pyrometer repair department should have the following equipment, as well as the customary tools of the pocket variety issued to each serviceman:

1. Portable potentiometer, calibrated in millivolts, non-compensated type.
2. Portable potentiometer, calibrated in degrees F., compensated type.
3. Portable whetstone bridge.
4. Muffle furnace.
5. Battery box.
6. A standard iron-constantan, 20-gauge thermocouple with its calibration curve.
7. A standard chromel-alumel, 8-gauge thermocouple with its calibration curve.

The pyrometers used in the oil industry are precision instruments and to retain their accuracy and sensitivity it is necessary to treat them as such. With the exception of the pressure pyrometers, the recording types will need periodic cleaning and oiling. All moving parts with the exception of the clutch plates should be checked for proper lubrication and oiled when necessary at least once each month. Any dirt or accumulated oil should be wiped off the instrument at this time. The chart, pen and print-wheel ink pad should be replaced or refilled when necessary. At least once a month the galvanometer, of those instruments that use one, should be taken from the instrument and checked for balance. A condition of unbalance in the galvanometer will amplify any condition existing from excessive vibration.

When the thermocouple is used, its accuracy should be checked by comparing the actual tempera-

ture at the protecting well, as measured by a standard couple and a portable potentiometer against the indication at the instrument. This should be done as often as experience dictates is necessary on critical temperatures. This will give an accurate check on the deterioration of the thermocouple as well as indicate possible errors in the instrument or lead lines.

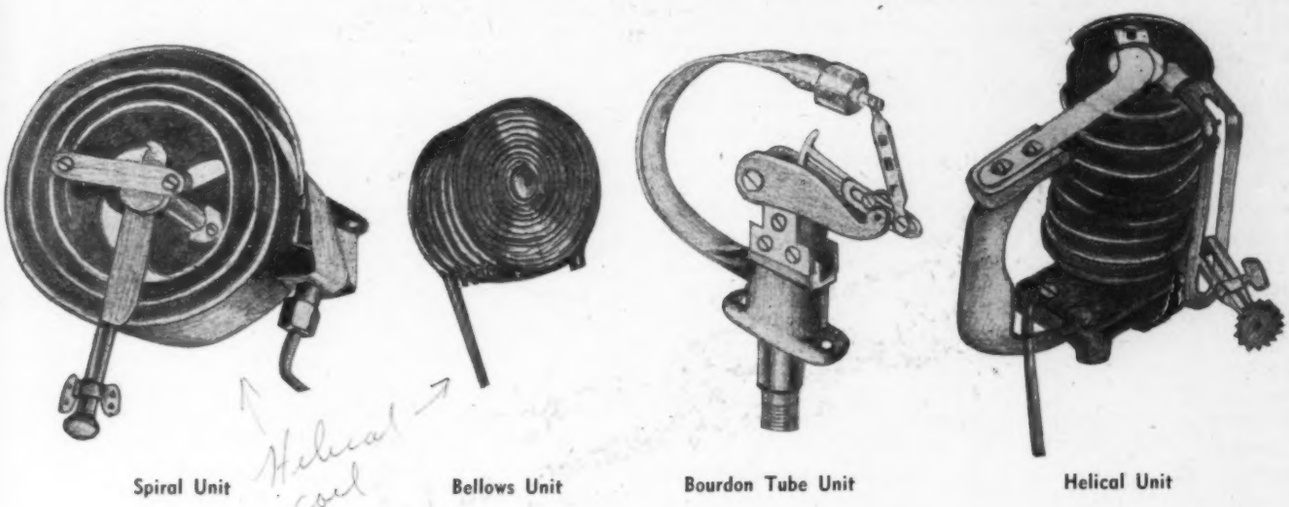
Thermocouples used in critical temperatures should be checked against a standard couple by inserting both in a small electric muffle furnace and the calibration curve of the standard couple compared with that of the thermocouple to be used. In the potentiometer, the battery current should be checked daily, if dry-cell batteries are used. If air cells are used this check can be made at intervals of every two weeks.

In the resistance thermometer, the accuracy of the instrument can be checked by replacing the bulb and lead lines with a calibratnig spool in the circuit. This should be done at intervals which experience teaches is most satisfactory.

The most common troubles that will be experienced in the maintenance of the pyrometer are:

1. Broken galvanometer suspension, where a galvanometer is used.
2. Dirty pivots, where pivots are used.
3. Thermocouple open circuited.
4. Galvanometer pointer and position feeling mechanism dirty.
5. Bad contacts.

Maintenance in the pressure thermometer is very limited as any repairs that are necessary to the instrument must be made at the factory.



Spiral Unit | Bellows Unit | Bourdon Tube Unit | Helical Unit

Pressure Instruments

The number of pressure gauges in the average refinery will far outnumber any of the other types of instruments, but as a general rule very little attention is given to the selection of this equipment. This is especially true when a replacement is necessary. As most often is the case, an exact duplicate of the previous instrument is purchased, and no consideration given the possibilities of changing process conditions or new developments in gauge design. In discussing the pressure gauge we include the measurement of vacuum, as there is no fundamental difference between the measurement of these two variables.

The pressure instruments in the oil refinery can be classed into four groups, bourdon-tube type, the helical-coil type, the spiral, and the manometer or draft gauge.

The most common type of indicating gauge is of the bourdon-tube type, which makes use of a bronze or steel tube elliptical in cross section and bent into a circular form. One end is silver or soft soldered to a socket that is rigidly attached to the case. In applications of high pressure, the tube is sometimes screwed or welded into the socket. The free end is sealed with a plug and will expand with an increase of pressure. When pressure is applied to the tube, it tends to lose its elliptical shape and to straighten out, which moves the closed end, which through a connecting linkage turns a gear segment. The movement of the gear segment rotates the gear pinion, and a pointer on an extension of the pinion shaft will move over the scale, generally calibrated in pounds per square inch.

The second type of pressure-sensitive element used in the construction of pressure gauges is the spiral. The development of this unit was necessary because the restricted movement of the bourdon tube made it impossible to use this form in the majority of recording gauges. In this case the tube would have to be very large to have sufficient tip movement to operate the necessary linkage for a pen to travel across a 10- or 12-inch chart.

The spiral type of element is fundamentally a series of bourdon tubes, with the movement of each succeeding tube added to the movement of the one preceding it. This in effect will amplify the movement of the tip sufficiently to actuate a pen arm. When the necessary linkage is installed to the pen movement, a sensitive recording pressure gauge is the result.

The third type of element used in the recording pressure gauge is the helical spiral. Here again, we find a variation of the bourdon tube principle applied to pressure measurement. This unit is wound in spiral shape around a central shaft, one end of which is attached to the tip of the spiral helix, while the other end of the shaft is attached to the pen mechanism. Any movement of the tip will be transmitted to the pen mechanism and the pen will indicate the pressure on a calibrated chart.

Selection of the proper materials for the construction of the preceding types of pressure-sensitive

elements will depend entirely on the fluid to be measured, and conditions of vibration or pulsation that might be encountered. The general characteristics of the metal selected must be such as to show little if any tendency to creep or develop hysterisis at relative high pressures. It must resist fatigue stresses imposed upon it. These fatigue stresses will be more dominant in the applications where pulsations and rapid vibrations occur. The metal must resist the corrosive action of the fluid being measured. The metals commonly used for this service are, phospor bronze, alloy steel, stainless steel, and beryllium copper.

The fourth type of instrument for measuring pressures in the refinery makes use of the manometer principle. The principle is the same as that of the U-tube flow meter. A glass U-tube is filled with water or some other liquid of known specific gravity and a scale placed behind the tube. This scale is calibrated in inches of water, a pressure tap is connected to one end of the U-tube and a difference of pressure is noticed between the unknown and atmospheric pressure. To improve the accuracy of the readings, the manometer or draft gauge is generally placed on an incline, which will result in the movement of the liquid in the gauge giving an amplified reading on the scale. This instrument has a definitely limited range.

The selection of the proper type of instrument for pressure measurement depends upon whether a recording or a simple indicating type is desired. For simple indicating gauges, the bourdon tube is universally used. In cases where it is desired to have a recording of the pressure, a more complex instrument is necessary and either the spiral or the helix type is specified. On pressures of 100 pounds or less the spiral system is used, but on pressure in excess of 100 pounds the helical movement is preferred.

Little can be said about the installation of the pressure-indicating devices. There are a few fundamental rules to follow and the observance of these rules will lead to satisfactory service of the gauge. If possible, the gauge should be equipped with a needle valve and union below the socket. A pipe tee, nipple and valve should be installed above the union to bleed the pressure from the gauge, so an accurate zero check can be obtained. This tap can also be used for checking the accuracy of the gauge against a previously checked test gauge.

Where excessive vibration is present, a "gauge saver" or "snubber" should be installed. This can be of any of the commercial types or very satisfactory results can be obtained by installing several coils of pipe preceding the gauge.

Where corrosive liquids may enter the tube system, protection must be used. There are many types of protertors on the market, but the most successful uses a diaphragm to separate the line fluid from the gauge. In this type, the bourdon tube and the area above the diaphragm must be filled with a non-compressible medium. The most common medium used for this purpose is a 50-50 solution of glycerine and water. In some cases a light lubricating oil is used, usually SAE 10 or lighter.

The temperature of the liquid entering the gauge should not exceed 150° F. A siphon must be installed on applications where the temperature will exceed this limit. periodic shutting down of the equipment will drain the gauge and the connecting piping, and the subsequent recharging will be of higher-temperature fluid. This protection is necessary in all steam-gauge installations.

Consideration must be given to the correction for liquid head where the gauge is installed above or below the pressure tap. When the gauge is installed below the tap, the indicated pressure will be high, and when the gauge is installed above the tap the indicated pressure will be low. This applies particularly to liquids, and in the case of a gas where condensates may make a liquid head possible. The correction for this error is made by the adjustment of the pen position on the chart or scale.

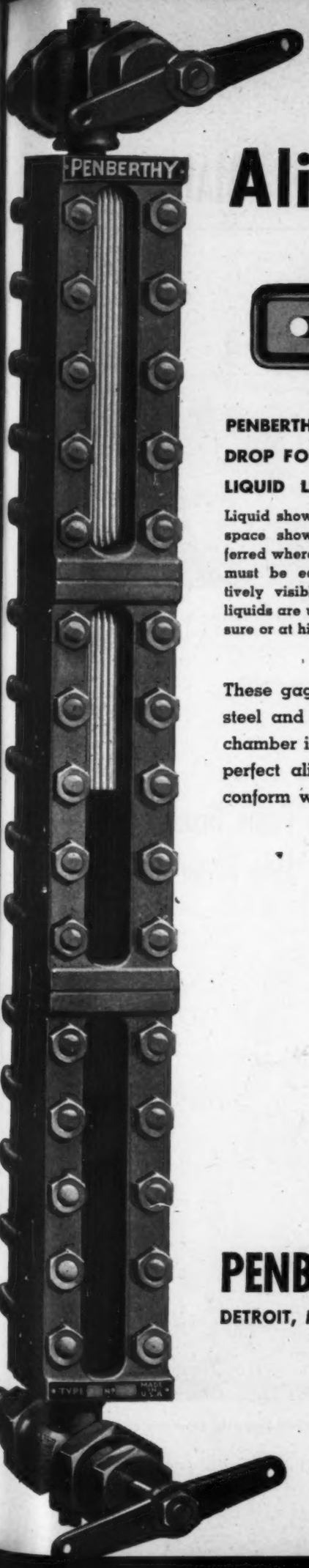
Maintenance of Pressure Gauges

Maintenance of the pressure gauges of the modern refinery is limited to the cleaning of the bearings, pinions and the gear segments and periodic checking of the accuracy of the gauge. The accuracy is checked by comparing the gauge against a deadweight tester or a previously checked and accurate test gauge. Any adjustment necessary on the gauge because of the drift or set of the tube can be made by the instrument man in the shop. Besides the adjustment for a lineal error, sometimes it is necessary to correct for an angular error. This is simply done, in principle, by changing the radius of the pen or pointer linkage in relation to the movement of the pressure-sensitive element. The gauge should be calibrated and adjusted to the tolerances required by the application. An accuracy of $\pm$ 1 percent of scale range is possible. A system of periodic testing of pressure gauges should be used in all plants.

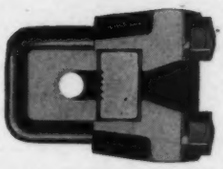
As previously stated the measurement of vacuum has similar problems comparable to the measurement of a positive pressure and the average vacuum gauge would be treated as a pressure indicator. But because of one important point we consider the compound gauge. The compound gauge will indicate either pressure or vacuum. The pointer taking a position on the scale at zero dependent upon the range of the instrument. At a positive pressure of 15 pounds and a vacuum of 30 inches, a 30-pound bourdon tube unit is used and the scale will have zero at the "twelve o'clock" or straight up position. And at a pressure of 60 pounds and a vacuum of 30 inches, a 60-pound tube is used and a scale will have zero to the left of the straight-up position. As the pressure of the positive side increases the graduations of the scale for the vacuum side decreases. This obviously has its readability limits.

Another type of pressure gauge, used on very small pressures is the metallic-diaphragm type. This gauge consists of a metal diaphragm built into a housing and a connecting linkage to the pointer installed. As one side of the diaphragm is exposed to changes in the pressure the diaphragm will distort in proportion to the pressure. But is only applicable to very low pressure.

The bell type of pressure measurement also is used. In principle it consists of a bell suspended from one side of a pivoted lever arm with a balanced weight suspended from the other side of the arm. The lower end of the bell is immersed in liquid and a pressure tap is extended into the bell above the liquid level. The system is balanced when the pressure is at zero and any change in pressure at the pressure tap will upset the equilibrium of the system and an indication of this change can be transmitted to a recording device. This instrument is especially valuable where very small changes in the pressure should be indicated.



Alike in Quality



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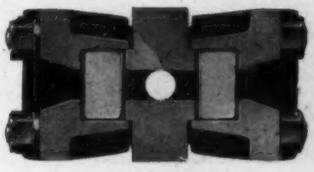
LIQUID LEVEL GAGES

Liquid shows black—empty space shows white. Preferred wherever liquid level must be easily and positively visible... and when liquids are under high pressure or at high temperature.

These gages are made of alloy temperature resisting steel and are the highest quality throughout. Liquid chamber is made from a solid block of steel to assure perfect alignment and rigidity. All Penberthy gages conform with A.P.I.-A.S.M.E. requirements.



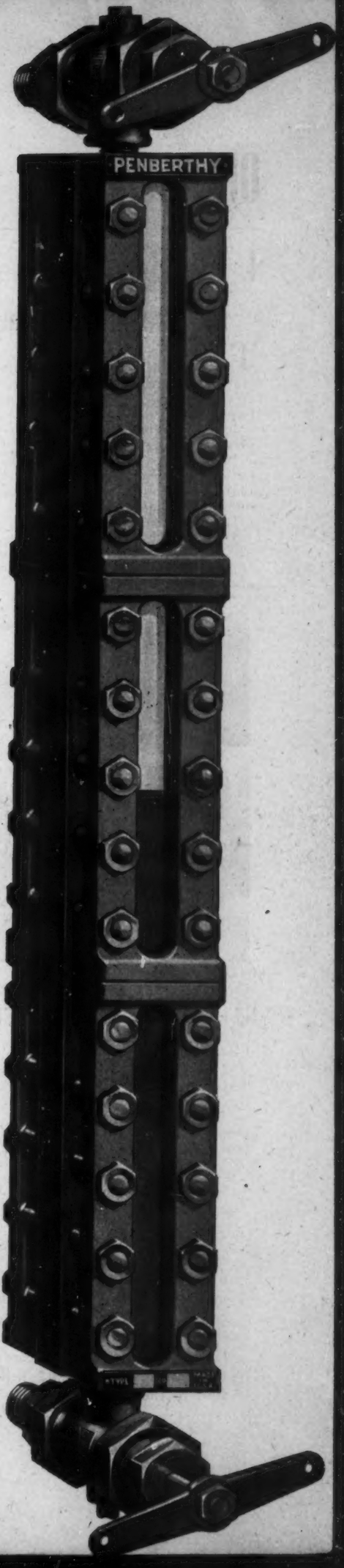
PENBERTHY
Transparent
DROP FORGED STEEL
LIQUID LEVEL GAGES

Used to observe color and density of liquids under high pressures, and/or temperatures. Construction is exceptionally rugged . . . similar to Reflex types.

PENBERTHY INJECTOR CO.

DETROIT, MICHIGAN • **Canadian Plant; Windsor, Ontario**

PENBERTHY PRODUCTS



OPERATION HOW TO DO IT MAINTENANCE

1. Truck-Loading Rack For Handling Butane

THIS loading rack for handling butane is without frills or complicated arrangements. It is built as simply as possible in order to deliver a maximum volume of liquid so that truck convoys may be loaded with dispatch.

Location is outside the plant yard but near enough to plant storage tanks that a minimum length of lines is required for liquid and returning vapor.

Loading lines from the tanks in the yard terminate in short risers which are connected to two horizontal lines supported by solidly-set posts at each end. Protection for the rack is provided by fixtures mounted on pipe posts back of the rack.

This butane loading rack has two sets of piping for liquid delivery and vapor return. The lower picture shows connections on the truck.

The loading area is covered with uniformly sized gravel to provide a dry working area for the men.

Capacity of the rack pictured is approximately 6000 gallons per hour.

vided by setting inverted U-shaped pipe barricades at each end, and painting them black and white striped for visibility.

High-pressure hose, both for liquids and vapors, are connected to the piping. These lines have approved unions at the truck end, together with control valves so that emergency shutoff may be obtained immediately. Static-bleeder cables are installed so that the free end can be attached to the truck by alligator clips.

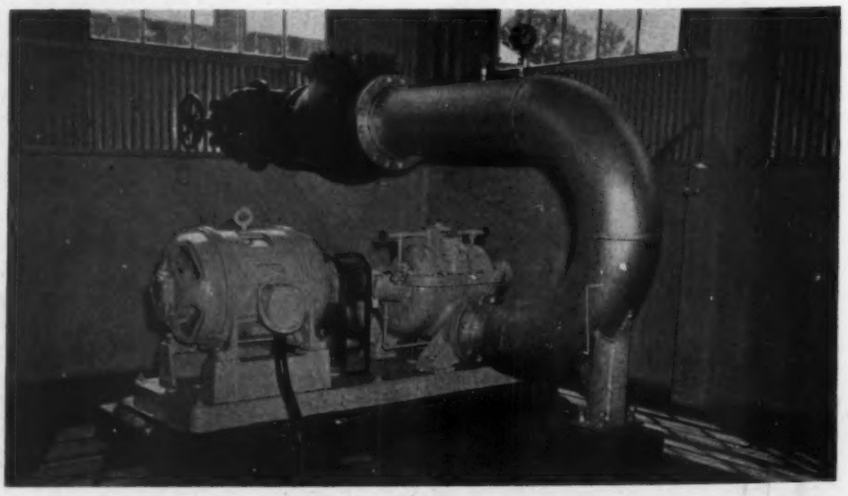
Floodlighting for night leading is pro-

THE WINNER

A number of readers selected at random and asked to evaluate items printed in this department in February have indicated the award should go to Item 4 — Turbine Profits from High Efflux Pressure. Accordingly, a $25 Victory Bond will be sent to the contributor.

2. Pump Discharge Line Support

DESIGN of a transfer-pump from sometimes makes it desirable that the intake and discharge lines enter the building from the same side, although at different levels. Such a layout usually involves bringing the lines into the building with 90-degree ells for tying the two to the pump flanges, and requires exact



Floating foot supports pump discharge line without hindering expansion or vibration.

Some refineries have found it well worth while to install traps in lines of any length, to remove moisture, which will otherwise sludge the lubricating oil . . .

Practically all refinery cleaners are air-driven . . . therefore it seems logical to start an investigation at the source of power — the compressors. Assuming them in good condition, check each air line for pressure drop . . .

Hose couplings are frequently a source of trouble which is often due to the hose becoming oil soaked at the motor coupling, allowing it to pull loose . . .

The motor must have enough air pressure to provide the necessary speed to enable cutters to *penetrate* rather than grind out the coke. However, above a certain peripheral speed cutters and fins will turn blue and lose their hardness. Thus motors and heads should be matched . . .

Another source of coupling trouble is with the nipple on the motor end of the hose coupling. If the motor is not threaded all the way on the hose nipple, the nipple may snap under heavy vibration . . .

"How much oil does a cleaner require?" This obviously depends upon the size of cleaner and type of oil . . . The only sure test should be a film of oil on the exhaust ports of the motor after it has been run . . . Oil is cheap compared to burned-out motors . . .

The greatest problem in tube cleaner work is the correct selection of cutter head . . . More heads have failed because of incorrect application than for any other reason . . .

The hose is just as important as the cleaner and should be checked often . . .

Practically all cutter heads are self-feeding. Let the cleaner feed slowly and evenly and if necessary hold it back slightly, and the head will not jump coke . . .

How to
make tube cleaners
last longer—
work faster—
clean better—
An authoritative article by L. A. Kunzler, tube cleaner specialist, reprinted from PETROLEUM REFINER and distributed by ELLIOTT COMPANY, Springfield, O.

Here's really informative data on tube cleaning

The above extracts will give you an idea of the character of this bulletin. It is rich in vital factual material gathered the hard way—through life-time experience. The bulletin is a reprint of an article from "Petroleum Refiner" by Mr. L. A. Kunzler, Sales Manager of Elliott Company's Tube Cleaner Department. It is *not* a treatise on Elliott tube cleaners, but a valuable dissertation on methods of speeding and bettering the tube cleaning job, by a veteran specialist in the business. Every maintenance engineer will want one or more copies—free at your request.

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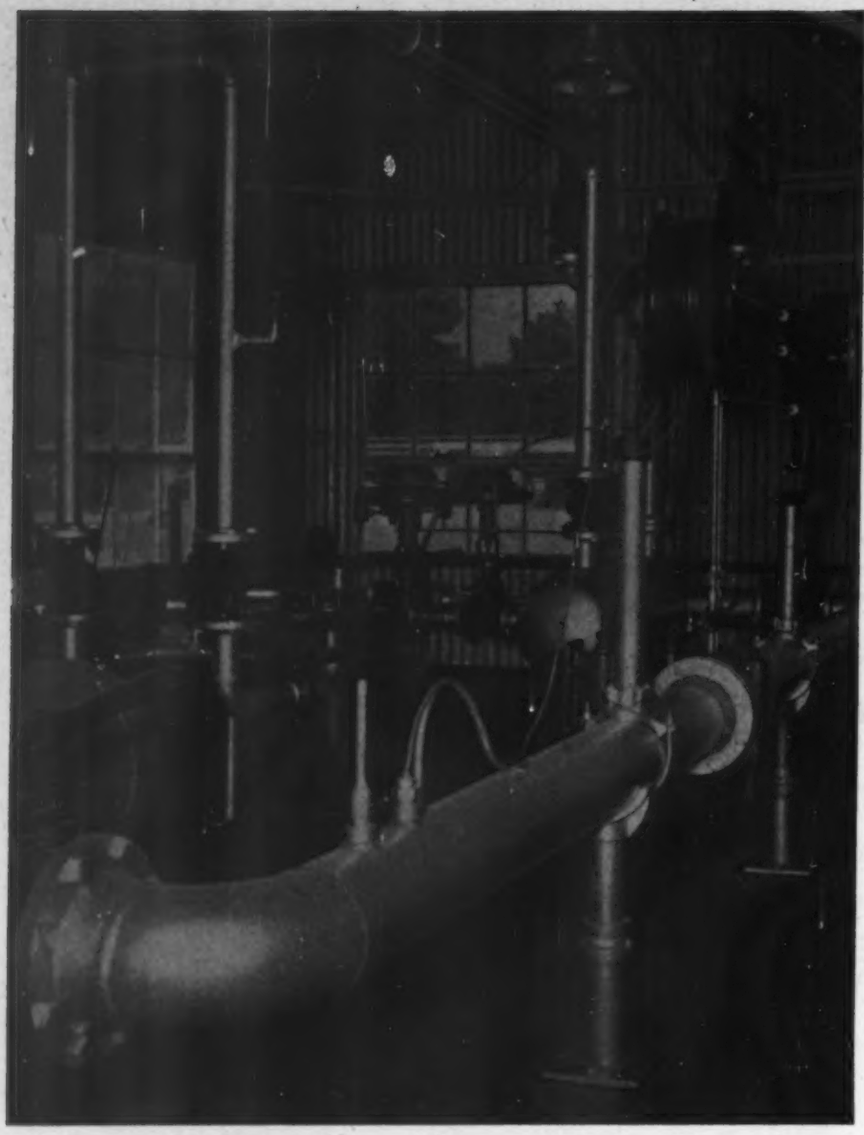
ELLIOTT- *TUBE CLEANER HEADQUARTERS*



Groove on pipe supports tubing and leaves it free for expansion without stress at either end.

fitting of both lines, with no provision in the design for expansion shifts.

One plant adhered to the scheme of carrying both lines in a common trench, with the suction line tied directly to the pump flange without change or direction. This plan involved an 180-degree turn in the discharge line, which was made by joining two swaged, tapering ells, so that the cross-section of the line increased regularly as the distance from the discharge flange increased.

Weight of this reverse bend and the accompanying check valve and block gate was divided between the support at the pump-room wall and a floating foot on the lower swage fitting. The foot consisted of a built-up section of steel, formed to fit the curve of the swage at the top and having a broad, flat plate for base. This base carried four hardened, ball-pointed set screws, each with lock nut.

The set screw points bore on a hard-faced steel plate, let into the top of a short concrete pier. The pedestal was to take weight only, and the entire discharge line was left to shift laterally under expansion, or to adjust itself along the axis of the pump to accomodate vibration and settlement stresses. When adjusting the four bearing screws, a torque wrench was used to distribute the weight of the return bend equally over the four screws, alignment of the flanges being checked with a gauge before the bolts there were placed.

3. Support for Recorder Connection Tubing

INSTEAD of brining the pressure lead directly to the recording gauge, with only a short section of copper tubing to serve as absorber to minimize pulsations to the recording-pen mechanism, one plant places the tap for the pressure line six or more feet down stream from the pedestal carrying the gauge.

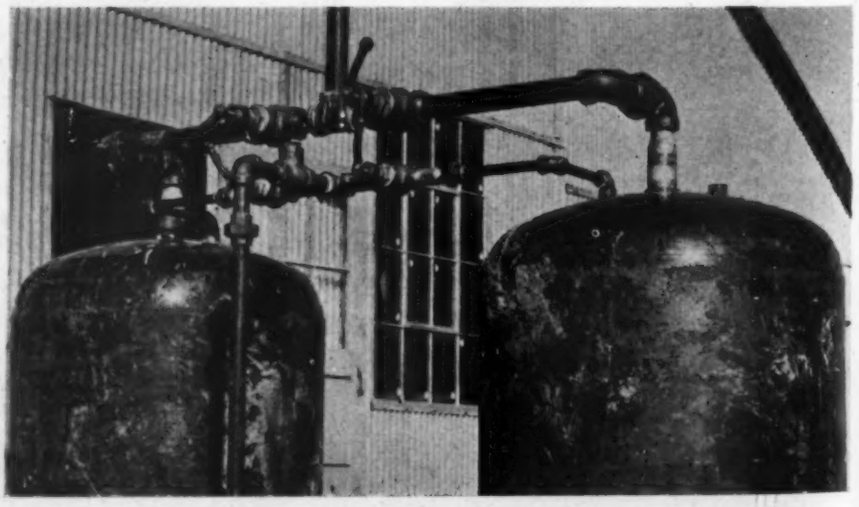
From this point the tubing is brought in a gradual curve through nearly 180 degrees until it nearly contacts the main again, then turns upward to reach the union at the back of the gauge. The tube is not fastened within the support, but merely laid in the shallow groove so that the tubing is free to expand or contract with pressure changes, without adding stress to either end connection.

A tubing section thus supported may be lifted free when it is necessary to disconnect it, and the change of direction at any one point is so slight that any danger of hardening or crystallization through cold-working is eliminated.

The support for the tubing is made from a joint of iron pipe, split longitudinally, formed to approximate a sine curve and welded to the collar carrying the reducer connection and again where the reverse curve contacts the main pipe wall.

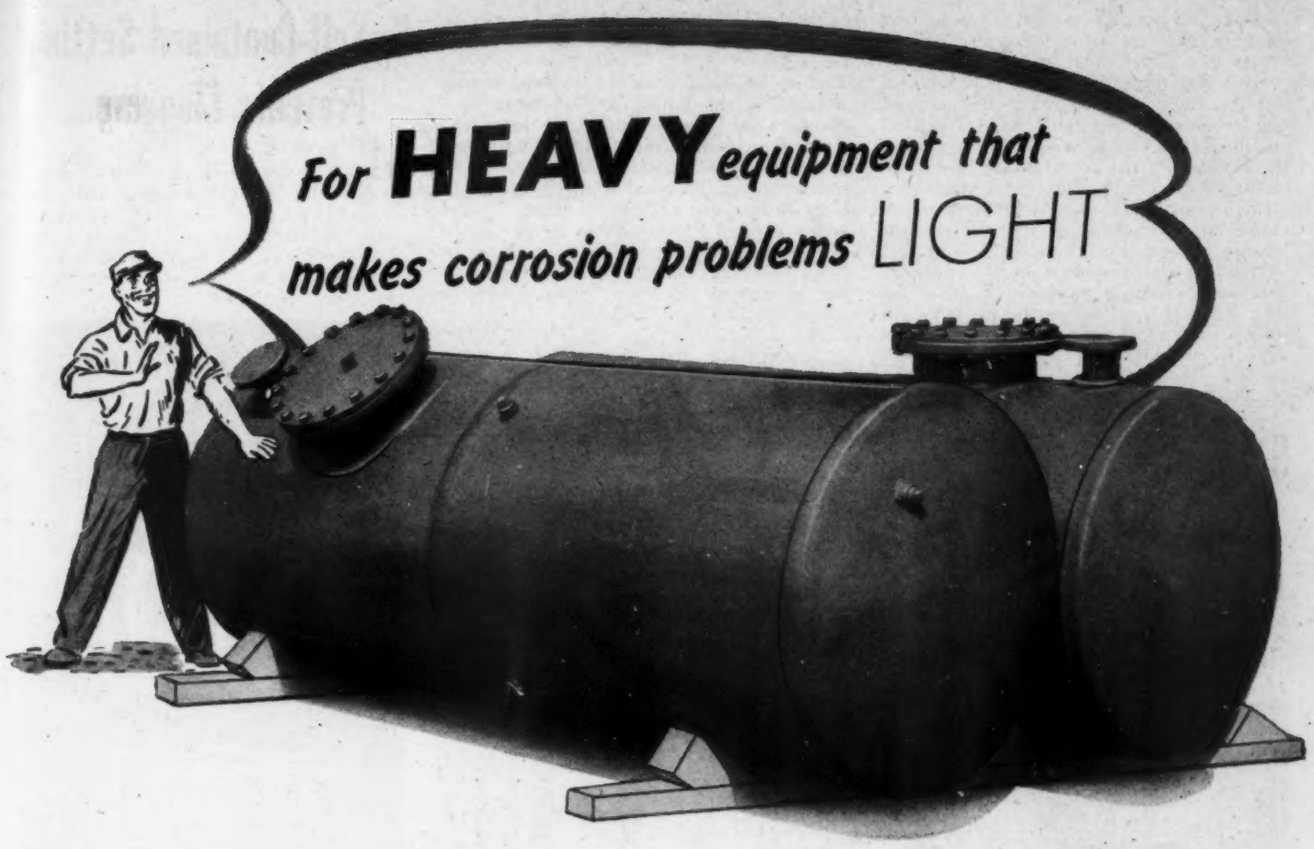
4. Swings on Air Tanks Curb Expansion Damage

CONNECTIONS to dual storage tanks for compressed air for engine starting, processing and instrument operation are subject to sudden and quite severe expansion and contraction stresses as the tanks are alternately charged with heated air and then the high-pressure air is drawn off, with consequent pressure reduction and resultant temperature drop. If the connections are made as direct as possible, this alternating stress frequently causes breakage at threaded



This piping on air tanks prevents damage from temperature expansion and contraction.

For HEAVY equipment that makes corrosion problems LIGHT



In your battle for product purity, corrosion is a constant enemy.

However, it's an enemy that refiners can overcome... with Monel* equipment.

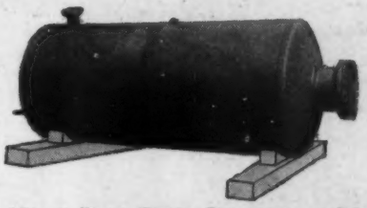
The tanks and vessels illustrated here, for example, were constructed of Lukens Monel-clad steel by The Downingtown Iron Works, Downingtown, Pa. Used by The Atlantic Refining Company in the manufacture of their synthetic detergent, *Atlantic Ultrawet,* this equipment was made after tests had demonstrated Monel's excellent resistance to corrosion and its ability to safeguard product purity.

For heavy equipment like this, Lukens Monel-clad steel offers all the corrosion-resistant properties of Monel — all the strength, toughness and other characteristics of the solid metal — *at considerably lower cost.*

By the Lukens process, a layer of Monel (usually equal to 10% of the total plate thickness) is bonded to a heavier layer of steel. Forming, bending, flanging, welding and similar fabrication operations do not cause buckling or cracking. *The bond is permanent.* No separation of the layers occurs under normal conditions of temperature change, pressure, vacuum or mechanical shock.

Further information concerning the advantages of this cost-saving construction material is contained in the illustrated booklet, *Lukens Clad Steels.* Refiners interested in minimizing corrosion and metallic contamination will find it helpful. A request on your business letterhead will bring your copy promptly. Write today. *Reg. U. S. Pat. Off.

THESE 1,000-GALLON *process tanks are constructed of 10% Monel-clad steel. They were made by The Downingtown Iron Works for The Atlantic Refining Company.* Photos on this page by courtesy of Lukens Steel Company.



MONEL-CLAD STEEL PROTECTS *purity of* Atlantic Ultrawet, *a synthetic detergent made from petroleum in this 2,000-gallon batch still.*

800-GALLON AGITATOR MIXER. *Fabricated of 20% Monel-clad steel by The Downingtown Iron Works, it will serve long and dependably under highly corrosive conditions.*

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sections, or may even pull a line in two if the tanks are heavy enough or are firmly tied down.

By offsetting the lines with paired swings soon after leaving the tapped connections in the tank heads, sufficient flexibility is designed into the piping to enable it to accomodate itself to changes in length, the variation being absorbed by the threaded fittings, which make up or back off slightly when adjusting to new conditions.

Use of swing connections also permits the replacement of a valve or other fitting without need for straining adjacent joints, or for obtaining additional clearance by moving one or both of the receivers.

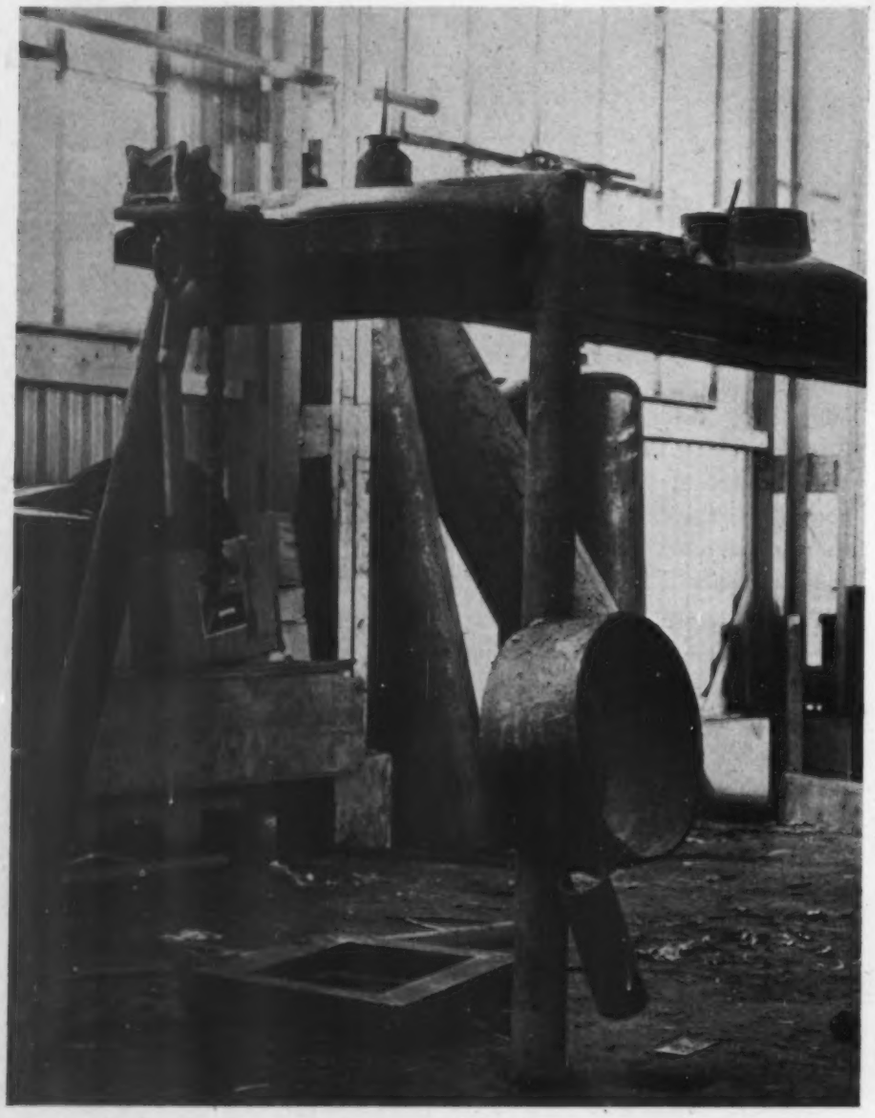
5. Jig for Bending Pipe and Conduit

FORMING conduits and various oil and other piping in a compressor plant was simplified and made uniform by means of a simple device attached to one of the legs of the portable workbench on which the various pieces were cut and threaded.

A short section of 12-inch pipe was welded to the bench leg, about a foot above floor. Below the big pipe was welded an 8-inch nipple of 2-inch pipe, so set as to bring its axis tangential to the big pipe. To bend a curve with a 6-inch radius on a piece of pipe, it was necessary only to stick one free end into the socket of 2-inch pipe, and then to bend the length around the 12-inch collar or sleeve until the desired arc of curvature had been attained.

Where several lines were to be supported in one plane, one above another, accurate alignment of the units was obtained by marking each free end before inserting it into the socket, the marks being laid out to carry the curved sections progressively nearer to or farther from the bend.

With the radius of the forming device, it was not necessary to fill the pipes to be bent, to prevent collapse or crimping, while the sliding support afforded by the socket eliminated die or vise marks which sometimes cause failure when pipe is so clamped while being formed to special contours.



Portable work bench for pipe threading equipped with simple and effective means of bending pipe.

6. Self-Contained Setting Prevents Clogging

MANY floor sump systems depend upon a relatively small cast strainer fitted around the foot valve to protect the pump against damage through trash picked up with the fluid to be removed, only to have the strainer clog and the pump kick off with a pit full of liquid to hamper the cleaning of the unit.

Slots in barrel minimize chance of sump clogging up.

One method for avoiding this trouble is in the use of a floor-level strainer such as the one shown. Here a 3-foot-diameter steel tank has been buried in the concrete floor of the pump room and the floor troweled to provide natural drainage to this lowest point. At the line where the concrete meets the tank wall a series of slots is cut through the steel, at intervals of about one inch. These narrow slots, extending entirely around the circumference of the shallow tank, provide ample drainway to admit a volume of fluid greater than the pump can handle. Even if half of the gaps are temporarily blocked off by paper, sticks or other floating debris, the area of the

EACH month the operating personnel in the refining, cycling and natural-gasoline plants determine the winner of a War Bond, maturity value $25.00.

Superintendents, assistant superintendents and foremen (subscribers as well as non-subscribers) become a jury to select the most practical contribution to this deparement on maintenance and operation. The editors rotate voting among men qualified to determine the rating.

This award is in addition to payment for the article. The methods of solving plant operation and maintenance problems come from the personnel of the industry. Items provided by Petroleum Refiner staff members will not be eligible.

Send contributions to Petroleum Refiner, P. O. Box 2608, Houston 1, Texas.

AT BORGER, TEXAS...
a sound investment indeed!

Power for all electrical equipment in the entire synthetic rubber project at Borger, Texas, is supplied by 18 efficient GMV gas engines driving generators. Installed in the government-owned Phillips Petroleum Company operated butadiene plant where rated capacity is 45,000 short tons per year, these Cooper-Bessemer 10-cylinder V-type engines also supply all electrical power for the directly adjacent copolymer plant where the butadiene is received by pipeline and converted into raw synthetic rubber.

These compact, 1000 hp GMV's are a sound investment indeed. They have been operating in this plant for well over two years, giving economical, trouble-free service. Years from now their performance will be just as creditable. But there's much more to say for these modern Cooper-Bessemer engines. They are extremely versatile — ready for the future whatever it may bring!

For example, next year or ten years from now they can be quickly, easily changed to compressor units, should this become desirable. No reconstruction, no major part replacements. Standard or specially designed Cooper-Bessemer compressor cylinders can readily be attached, converting the units into direct-drive, V-angle compressors. And, since all crankthrows are available for driving compressor cylinders, each engine can power 1, 2, 3, 4, or 5 cylinders, as required, for any pressure or volume within the horsepower range.

Add exceptional efficiency and long, economical service life to unusual versatility, and you can see that GMV's are always a sound, well-protected investment. The nearest Cooper-Bessemer office welcomes a discussion of your particular engine requirements for today . . . with an eye to the future.

by **Cooper-Bessemer**

MOUNT VERNON, OHIO AND GROVE CITY, PENNA.

Houston, Dallas, Greggton, Pampa and Odessa, Texas Tulsa Shreveport St. Louis Los Angeles

Bucket rack prevents spilling plastic materials hoisted to high levels.

openings still serviceable will care for a heavy run off, and aid in keeping the floor dry.

The pump, if provided with automatic on-and-off float switch, will operate to maintain minimum fluid level in the screened sump. Depth of the tank may be varied to accomodate estimated run-off from any pump casing or to handle water if the floor be hosed down at intervals to remove dirt or oil.

To protect the sump against corrosion, the entire tank is coated with a bituminous paint after the slots are cut, so that the metal exposed by the cutting torch is also coated against damage.

7. Gang Lift for Buckets For Plastic Materials

HANDLING of plastic or semi-liquid substances to points high on cat-crackers and other elevated structures requires the use of 10- or 12-quart buckets, so that the quantity sent up can be readily handled by the man working on the scaffold or ladder.

Hoisting of these buckets of material usually results in damage to the containers and wastage of contents if an attempt is made to move several units at once on a single hook or sling. To avoid these difficulties, one company had welded a rack which used angle iron, supported by paired suspending loops of bar stock, leveled by a clevis to lift without canting.

Suspended below the rack are a number of pig-tailed hooks, so spaced that buckets hung on them do not strike one another during a lift. The hook for the bail makes more than a full turn, to forestall accidental unhooking of a bucket during a lift.

With such a rack several workmen may be supplied with material at one hoist, buckets being unhooked at the various scaffolds or working points without interfering with the others. By rotating the rack as it is suspended on the hoisting line, removal may be regulated to preserve the balance of the remaining units.

Hooking on of the filled buckets is done while the rack is held at a convenient distance from the ground, being controlled by signals from the ground attendant to the hoisting engineer or by locking the drum at the desired point if one man handles both jobs.

The damaged buckets shown in the photograph were bent by being dropped from the scaffolds or hammered to free their contents, and not while being hoisted while suspended on the hooks.

8. Hydrometer Cylinder Speeds Work

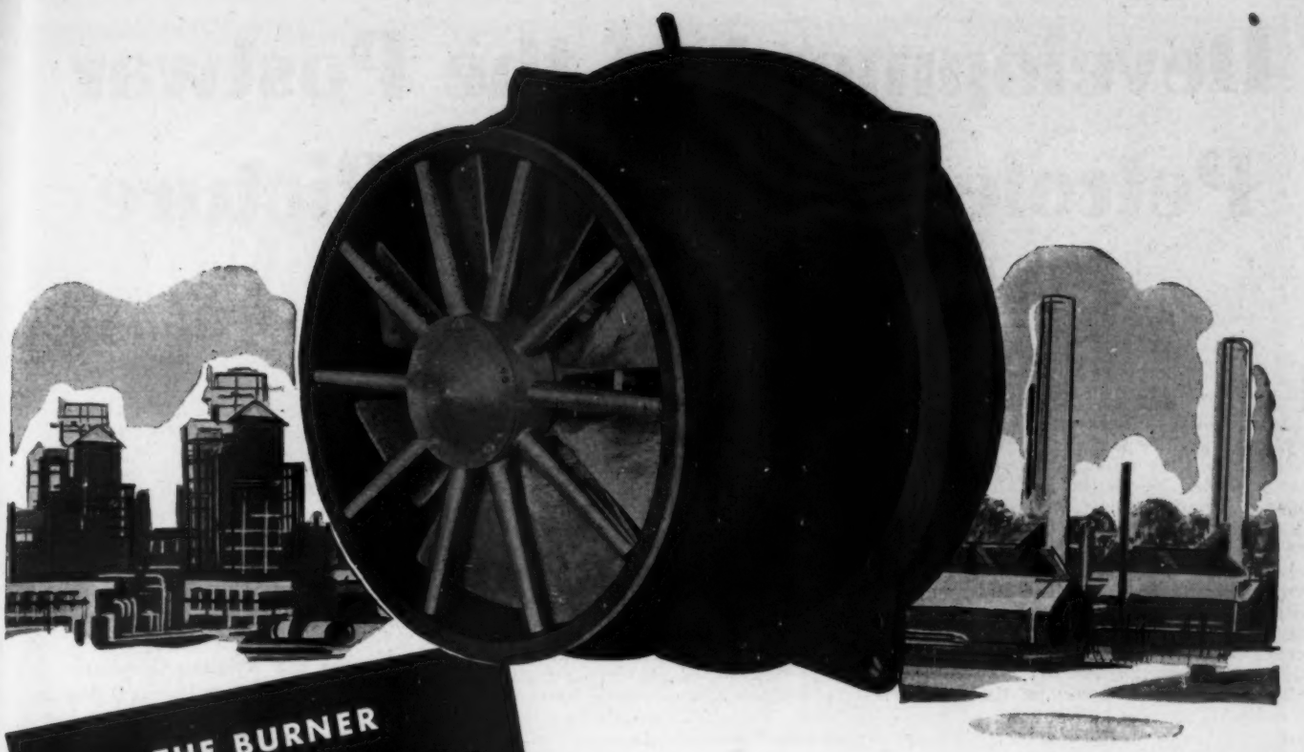
THE metal cylinder carried by the gauger or operator for drawing a sample of the fluid being tested for gravity was improved by one operator to speed his work and also to eliminate much of the spilling which not only introduced a fire hazard but also required additional cleaning around the sampling stand.

A V-shaped notch, cut down from the top to permit a spout to be soldered on made the emptying of the cylinder easier and eliminated the wetting of the outer surface by the liquid. By measuring the depth of the V so that the sample, when drawn just to the base of the spout, would come almost but not quite to the top of the container when the hydrometer was placed in the liquid, a uniform line of sight for all samples was assured and overflowing of the cylinder, by misjudging the amount of clearance required for the testing instrument, was avoided.

By placing a handle on the side of the cylinder opposite the spout, emptying of the cylinder is made easy, and the flow directed in such a way as to keep the sides of the cylinder clean. Forming the handle in the shape of a "P" instead of an arc of a circle shifts the weight so that the base of the cylinder is carried low, permitting the hydrometer to be carried within the unit without danger of spilling out or dropping.

Hydrometer Cylinder.

READERS ARE URGED TO CONTRIBUTE items to this department. Drawings or photographs are desired where practical. Payment for items accepted will be on a basis that will compensate for the time involved and in addition each contribution will be eligible to receive the bond award as outlined in the announcement on page 166. Jury awards will be announced in the second issue after publication.



THE BURNER that makes a new Boiler EASIER TO BUY

***Thorough, accurate mixing of fuel and air . . . complete combustion . . . with Coppus-Dennis* FANMIX**

When planning new gas or oil fired boilers, you can count on investing less in boiler, stack and auxiliary equipment — if you select a Coppus-Dennis FANMIX Burner. Coppus equipment was used for instance in 93% of 191 petroleum refinery plants built for war use.

FANMIX Saves Combustion Space

FANMIX delivers to the furnace a homogeneous mixture of fuel and air, without blow-torch action. Combustion is rapid and complete — so smaller combustion space is needed than when the furnace must serve as mixing chamber as well — or ratings of present equipment can be increased.

FANMIX Creates Own Forced Draft

Less furnace draft is needed than with any other burner, because FANMIX creates its own forced draft, thus overcoming draft loss across the burner (at any operating range). Less stack is needed, and forced draft equipment can be eliminated entirely.

There are two FANMIX types—one to handle natural gas, the other a combination type to burn either gas or oil in entirety or gas and oil in any proportion. (No oil guns needed).

Coppus engineers FANMIX Burners for individual applications. Complete control over rate of combustion or "flame pattern" can be provided to meet the requirements of any installation. Coppus Engineering Corporation, 524 Park Ave., Worcester 2, Mass. Sales offices in THOMAS' REGISTER. Other Coppus "Blue Ribbon" products in SWEET'S, CHEMICAL ENGINEERING CATALOG, REFINERY CATALOG.

New Bulletin Will Help You When Installing New Equipment or Modernizing Old

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Development of the Postwar Petroleum Refining Picture

EUGENE R. SMOLEY and VERNON O. BOWLES
The Lummus Company

IN AN article published about one year ago[1], the authors attempted to analyze and predict postwar marketing situations and their effect on petroleum refinery processing on the basis of trends and information then available as well as to illustrate methods of determining the most profitable selections of processes required for refinery modernization programs. In this article an attempt will be made to amplify these earlier discussions on the basis of the developments which have taken place during the past twelve months.

The refining industry lost little time in swinging from the all-out war production program to meet the marketing conditions imposed by a combination of residual war requirements and an unrationed public eager to enjoy again the pleasure of unrestricted driving and well heated homes. The industry can look with pride upon the accomplishment of fulfilling the difficult market requirements imposed by the overnight change when hostilities were terminated and rationing of gasoline and distillate fuel was abruptly discontinued. The refining industry is now passing through a period of continually changing economy which will not become substantially stabilized until the international political situation as well as our domestic industrial conditions become reasonably settled. Although the oil industry seems to be working out its labor problems satisfactorily and has obtained well stabilized manufacturing conditions, its domestic markets on the other hand will reflect existing unsettled conditions in the basic manufacturing industries resulting from strikes and widespread shortages of material. For example, the delay in the production of automotive equipment will have a pronounced bearing upon the demand of gasoline and lubricating oils by the public, and work stoppages in the steel and electrical industry will result in reduced requirements for petroleum products. The political gyrations of the United Nations Organization and of various international oil commissions will continue to delay active rehabilitation and expansion of foreign properties. In addition, political disturbances such as have been taking place in certain localities will slow progress in these areas. The net result of all of these domestic and international disturbances will be a curtailment of crude processing through 1946. However, it is probable that in 1947 there will be an upturn in crude run resulting from an increase in domestic as well as foreign consumption of refined products.

World-Wide Considerations

Toward the close of the war, the United States was refining about 5,000,000 barrels per day of petroleum while foreign countries were refining nearly 2,000,000 barrels per day. Had the war lasted through 1946, it was expected that there would have been a total world-wide demand for petroleum of approximately 7,500,000 barrels per day. These values compare with a world-wide prewar petroleum crude run of about 6,000,000 barrels per day in 1941. Current trends indicate that during 1946 the petroleum refining rate will probably drop to approximately 4,400,000 barrels per day for the United States and 6,300,000 barrels per day world-wide. After international political conditions become more stabilized, and as soon as it becomes possible to market petroleum products on an economic basis, the market for all petroleum products in foreign fields will build up rapidly, probably as early as 1947, and will continue to expand for at least several years. The fact that the consumption of refined petroleum products in the United States has averaged approximately 9 barrels per capita while the foreign consumption has averaged something less than ½ barrel per capita indicates the tremendous potential for increased use of petroleum products in foreign fields. Of interest in this regard is the fact that at the close of the war approximately 73 percent of all petroleum was refined in the United States, 12 percent was refined in the Caribbean area, 8 percent in the Near and Middle East, 3 percent in Canada and approximately 2 percent was refined in Mexico and South America. Inasmuch as there is a great potential market in every foreign country including Russia, China and all of the nations of Europe as well as the Pan-American countries, it is predicted that during the next decade there will be a great expansion of petroleum refining facilities abroad in order to supply these growing markets. Today American interests own 66 refineries abroad with an approximate total capacity of 875,000 barrels daily. United States' interest is 20 percent in the Middle East, 48 percent in South America, 35 percent in all foreign countries. American technologists will continue to play an important role in the development of these foreign projects and a considerable amount of American capital will be invested. There looms on the construction horizon four refineries to be built in the Caribbean area; there will be refinery expansion in the Persian Gulf and the Netherlands Indies, also in Latin America besides Venezuela, and in Canada. The other region due for great activity is the Caspian Basin. This will be carried out by Russia with some American engineering assistance and equipment. As soon as automobile manufacture is in full swing, it is predicted that average crude oil requirements in the United States will increase approximately 125,000 barrels per day each year. On the basis of a present domestic crude production of approximately 4,400,000 barrels per day, it is expected that a deficiency will develop in about 1947 making the importation of crude necessary in increasing amounts thereafter. This crude will probably be imported from the Caribbean and Persian Gulf areas.

Motor and Aviation Gasolines

With few exceptions the total demand in the United States for gasoline of all grades has increased every year. This increase amounted to approximately 4 percent annually during each of the four years preceding the war and in 1940 the gasoline demand reached a quantity of 1,700,000 barrels per day. Our participation in the war caused an increase in this demand to 1,900,000 for 1941 and to a peak of approximately 2,000,000 barrels per day in 1944. During 1944 and early 1945 more than 700,000 barrels per day of gasoline was produced for military requirements. This total included the production of more than 500,000 barrels per day of 100-octane aviation gasoline at the peak in the year 1945. Although gasoline rationing resulted in the release of a substantial quantity of the gasoline required for the military effort, it might be said that the major portion of this gasoline was obtained by virtue of sharply increased crude runs which rose more than 1,000,000 barrels per day to a peak of approximately 5,000,000 during the war years. The industry's ability to expand its refinery crude runs by such a substantial amount with only minor investment in new crude processing facilities is indicative of its ability to accommodate greatly increased demands for petroleum products during the next several years. With the facilities now available, the industry can process approximately 20 percent more crude than the anticipated 4,400,000 barrels per day for 1946, and with the new facilities in the course of construction and planning domestic crude runs approaching 6,000,000 barrels per day could be achieved. With this crude rate the normal gasoline production would be approximately 2,300,000 barrels per day.

The tremendous catalytic cracking capacity that was installed during the war years for the 100-octane aviation gasoline program has already reflected itself in motor-gasoline quality. It appears now that premium-grade gasolines will approach 85 ASTM motor method octane number during 1946, while regular-grade will reach approximately 80, and third-grade nearly 70. During the octane race of the prewar years, premium-grade gas-

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oline reached 80.2 octane number, regular 74.4 octane, and third-grade 65.6 octane number in 1941[2]. These octane values were sharply reduced during the war to 76, 72, and 55 respectively in order to facilitate the production of maximum 100-octane gasoline. Catalytic-cracking capacity in the United States at the present time amounts to approximately 1,000,000 barrels per day with nearly 100 plants in operation or under construction. The significant fact about this is its distribution. These 100 plants are located in only about 50 refineries of the 400 in the United States. The remaining 350 refineries with no catalytic units process over 40 percent of the petroleum refined in this country and with few exceptions these refineries run less than 20,000 barrels per day of crude. Most of these small refiners are giving serious consideration to the installation of facilities which will enable then to meet competition. Some of these refiners are fortunate enough to have available crudes which yield gasoline of suitable quality, but many, on the other hand, are already beginning to meet with difficulties in marketing their products. In at least three small refineries, catalytic-cracking plants ranging in capacity from 3000 to 6000 barrels per day are now in the course of design or construction. These refiners were able to justify the installation of small catalytic-cracking units not only on the basis of improved gasoline yield and quality but on the basis of increased over-all yield of liquid products and reduced production of residual fuel oils. Some refiners are meeting competition by reforming naphthas.

Engine Changes

By 1947 it is predicted that the automobile industry will commence producing engines designed for higher compression ratios resulting in more economical use of premium-grade gasolines. This development will be a gradual one and during its initial stages will not exert a great influence on the gasoline market; first because the percentage of high-compression cars will be small for quite a while, and second because owners of old cars are still purchasing a large amount of premium fuel. At the present time 40 percent of all motor gasoline sold is of premium grade as compared to 10 percent in 1941. This change is undoubtedly due to the desire on the part of car owners to employ the best quality fuel available in order to extend the life of their car and to obtain better performance. This tendency seems to be so great that even the 91-octane motor gasoline offered at certain pumps in California for a short time late last year, before the OPA enforced its discontinuance, received a very active public acceptance. In view of all of these considerations, there appears to be little doubt that automobile manufacturers will produce high-compression units designed to economically utilize gasoline of 85 to 90 ASTM octane number within the next two or three years.

Aviation Gasoline

In the field of aviation gasolines, it is predicted that there will be a gradual increase in consumption from the 35,000 barrels per day prewar level up to approximately 125,000 barrels per day by 1955. It is possible that there may be a limited use of super-fuels having higher octane than the military 100-octane aviation widely used during the war; however, present indications are that there is little to be gained by any increase in quality above 100 octane. Jet-propulsion engines designed to move planes at sonic speeds already appear to be displacing the gasoline-powered radial engines employed in military pursuit and attack planes. Inasmuch as jet-propulsion research is only in its infancy, it appears certain that kerosine-powered jet-propulsion engines will completely displace gasoline powered radial engines for nearly all military aircraft except possibly heavy bombers and reconnaissance planes. As metallurgical research provides the materials to permit higher-temperature operation in jet-propulsion units and thereby improves their efficiency, it is entirely possible that these engines also may enter into the commercial-aircraft field. Such developments will tend to reduce the requirement for 100-octane gasoline and increase the demand for kerosine-type fuels.

Distillate and Residual Fuel Oils

Although crude runs were increased by approximately 1,000,000 barrels per day during the war years, and although there was on the whole sufficient aviation and motor gasoline for military requirements, there was a substantial deficiency of both distillate and residual fuels during this period. This deficiency was corrected only at the expense of reducing the inventories of these fuels to extremely low levels by the end of the war. There is a rapidly rising trend toward the use of distillate fuels for home and industrial heating requirements as well as for stationary and mobile diesel-power units. The average demand for distillate fuels during the five years preceding the war increased by about 8.5 percent annually, indicating the rapid growth in the use of these fuels for domestic and industrial heating. It is anticipated that the total consumption of distillate fuels of 1950 will be nearly double that of 1940. This rapid increase in distillate-fuel requirements will be partly met by the addition of catalytically-cracked distillates and partly through increased refinery crude throughputs. Catalytic cracking of a large quantity of material which in the past has found its way into residual fuel oils will provide a significant part of the increased motor gasoline and distillate fuel requirements; however, this will probably bring about a deficiency in residual fuel oil supply. Although there have been periods in the past when it was not possible to market all of the residual fuel oils associated with gasoline market requirements, resulting in excessively large residual fuel oil inventory build-ups such as occurred in California during the middle 1930's, no such condition is again likely to arise regardless of the demands for other products. On the contrary, it is expected that the demands of increased industrial activity will bring about increased requirements for residual fuel oils. Any deficiency in residual fuel oil requirements will be met by additional refinery crude throughputs and it is probable that the marginal crude processed will be made up largely of imported low-gravity crudes. In general, it appears that the refining industry will encounter no difficulties in balancing its overall market requirements for several years to come. Use of existing catalytic cracking, coking, deasphalting and vacuum reduction facilities should enable refiners to balance the nation's gasoline, distillate fuel, and residual fuel requirements up to the extent of a total crude throughput in the range of 5,000,000 to 6,000,000 barrels per day.

Lubricating Oils and Waxes

While there was a vast program for construction of refining facilities primarily for the production of aviation gasoline during the war years, very few new facilities were installed for the manufacture of high-grade lubricating oils. During the war years it was possible to meet the military requirements for lubricating oils with the plants available. Last year the authors summarized the lubricating-oil situation describing the acceptance and growth of solvent refining during the decade preceding the World War. The large program for construction of new solvent-refining and dewaxing plants for lubricating-oil production is already under way in refineries on the Eastern Seaboard, Gulf Coast, Mid-Continent and Great Lakes areas. In addition to these projects now in the course of design and construction, a large number of additional projects are under active consideration and scheduled for construction within the next two years.

The trend among refiners is the production of higher-quality lubricating oils with increased flexibility and with maximum yields from crude at minimum costs. The installation of propane deasphalting units and efficient vacuum units will aid refiners in obtaining maximum yields of lube stocks and in affording flexibility for balancing viscosity requirements. Until substantial lubricating oil facilities are installed abroad, the large bulk of lubricating oils required for foreign markets will be produced in United States refineries. During the war years there was an extensive development of compounded lubricating oils containing a variety of additives including anti-oxidants, detergents, viscosity-index improvers, foam inhibitors, and pour-point depressants, most of which have been proven in service to prolong the life of aircraft and other military power units. The extensive use of additives not only facilitated the production of the required quantity of high-quality lubricating oils from limited facilities but in addition, imparted additional desirable properties to these oils unobtainable by other means. The extensive use of additives will undoubtedly continue and it is predicted that there will be a $100,000,000 annual market for these materials.

War Stimulation

War requirements stimulated the development of many new uses for micro-crystalline waxes, and during the five-year period from 1939 to 1944 production of micro-crystalline waxes increased six-fold to apporximately 120,000,000 pounds per year. These waxes played an important part in the military packaging program and it is expected that micro-crystalline wax manufacturing facilities will be expanded along with lubricating-oil refining facilities during the coming years in order to accomodate a further increased market for these waxes resulting from the war development of new uses for this product. It is significant that older methods of refining waxes are gradually being replaced by modern solvent methods, particularly in the field of micro-crystalline waxes. The sweating method for finishing crystalline

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C	8	46	7
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E	5	10	4
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waxes is still employed to a considerable extent. For increased production this process is being supplemented by several new installations of water-emulsion wax-deoiling units. Among the newest developments in solvent dewaxing have been the simultaneous production of marketable waxes along with low-pour lubricating oils. Commercial operation of the so-called reverse sequence solvent dewaxing will be under way shortly. There is some indication that the practice of chilling wax out of a rich oil-lean solvent solution results in the production of harder, more satisfactory crystals which contain less oil and yield a more highly refined product with lower solvent requirements. Continuous production of wax along with lubricating oils also shows an attendant saving in tankage and has some advantages from an operating standpoint.

Chemicals From Petroleum

The future will witness a broad and extensive development in the field of chemicals from petroleum. Although growing rapidly, this industry has already reached very substantial proportions. During 1944 approximately 3,000,000 pounds of chemical raw materials were produced from petroleum, doubling 1943 production. It is estimated that chemical, pharmaceutical and cosmetics manufacturers plan to invest a billion dollars in expanded facilities during the next five years. A substantial percentage of the raw materials which will be processed in these industries will originate from petroleum. Chemical raw materials produced in large volumes from petroleum are cheap and such products as ethylene and propylene used in the manufacture of plastics, alcohols and other synthetic organic chemicals are already in large-scale production. More than 1,000,000,000 pounds of ethylene and propylene roughly in equal proportions was employed for the production of synthetic organic chemicals during 1945. Large new plants for the production of further increased quantities of these two raw materials are now in the stages of design and construction and will shortly be placed in operation. Ketones, alcohols, ethers, esters, glycols, chlorinated hydrocarbons, styrene and plastics are among the many products derived from these raw materials. Other synthetic organic compounds manufactured from petroleum raw materials are useful in the production of dyes, pharmaceuticals, insecticides, textile finishes, laminates, adhesives and paints. In fact, more than half a million of the known organic chemicals can be produced from petroleum. In addition to the above mentioned petroleum derived chemicals, 63,000,000 gallons of nitration grade and 34,000,000 of aviation-grade toluene were manufactured from petroleum in 1944. This was approximately three quarters of the nation's total toluene production. Approximately 150,000,000 pounds of dyestuffs were produced in 1944 from raw materials derived from petroleum. The plastics industry which has already reached substantial proportions will be expanded tremendously in the coming years. Extensive research programs have been under way for several years with the result that plastics will find utilization for almost every conceivable object including not only accessories for automobiles, boats, radios, electrical equipment and clothing, but also for railroad car tops, boat hulls, prefabricated homes and oil-field equipment. Plastics is becoming a large tonnage industry and will therefore require raw material in quantities that the petroleum industry can readily supply. Thus the plastics industry will undoubtedly be closely linked with the petroleum industry. Synthetic-rubber plants built for and operated by the petroleum industry during the war were successful beyond all expectations. They played a major role in the nation's synthetic-rubber program which was so vital to the war effort. Several of the synthetic-rubber plants deriving their raw materials from petroleum have achieved such low operating costs that there appears to be no doubt as to their ability to maintain continued profitable operation.

Substitute Fuels

No discussion of the postwar petroleum refining picture would be complete without at least a mention of such subjects as liquid fuels from natural gas, shale, coal, or energy from nuclear fission. The production of gasoline from natural gas, shale or coal is not economical today. However, the Bureau of Mines as well as industry are studying and developing these processes for future application. With regard to atomic power, the scientists and engineers familiar with this subject predict its use for power in the far future, and its development will be watched with a great deal of interest.

[1] "Some Considerations of Postwar Petroleum Refinery Operations," Petroleum Engineer, May, 1945.

[2] These octane values are Bureau of Mines arithmetic averages for Winter 1940-41 of 21 districts of the United States.

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NGAA Silver Jubilee Program Features Process Technicalities and Corrosion

For its Silver Jubilee program in Dallas April 17, 18 and 19, the National Gasoline Association of America will give consideration to the problem of corrosion in gas-condensate wells as well as deal with the technical aspects of processing. The session of the first afternoon has been given over to problems in cycling-plant operation with corrosion in distillate wells the predominate topic.

For the second day the morning program will deal with processing of lighter hydrocarbons, with a session on economics in the afternoon.

The program of the third day will consist wholly of the "Information Please" session. In this a panel of experts in several phases of the natural-gasoline and cycling industry provides answers that come from the audience. This program is "off the record," a requirement set up so as to stimulate questions and discussion. This part of the program is scheduled for the morning of the final day but will be continued into the afternoon if interest justifies.

The Hanlon Award will be presented as the final part of the morning program on April 18.

That evening the Natural Gasoline Supply Men's Association will be host to those registered at the convention. A buffet supper and entertainment will be the only event of this nature.

Registration and committee meetings will take up the morning of April 17, leaving the first technical session for that afternoon. The following papers on cycling will be heard:

"Sampling of Two-Phase Gas Streams from Cycling Wells," Donald L. Katz, University of Michigan.

"Corrosion in High Pressure Gas Wells," T. S. Bacon, Lone Star Producing Company.

"Finding Corrosion Pits by Tubing Caliper," P. E. Chaney, Sun Oil Company.

"Reducing Corrosion in Cycling Wells by Injection of Chemical Inhibitors," C. K. Eilerts, United States Bureau of Mines.

The morning program for April 18 will be:

"Chemicals from Lighter Hydrocarbons," J. E. Bludworth, Celanese Corporation of America.

"High-Pressure Absorption," Henry N. Wade, Stearns-Roger Manufacturing Company.

"The Behavior of Hydrocarbon Materials in Condensate Reservoirs," Frank H. Dotterweich, Texas College of Arts & Industries.

In the afternoon subjects of economic significance will make up the papers and prepared discussions. Subjects are:

"Plans and Opportunities for the Natural Gasoline and Cycling Industries," J. H. Dunn, Shamrock Oil & Gas Corporation and president of the association.

"The Refiner Looks at Natural Gasoline," James W. Vaiden and F. E. Fisher, Skelly Oil Company.

"The Anti-Knock Properties of Materials Resulting from Superfractionation of Natural Gasoline," T. W. and H. R. Legatski, Phillips Petroleum Company.

The program for Friday will be devoted wholly to the arrangement for providing information through the question-and-answer session, "Information Please." The panel of experts will be: in process and design, M. H. Kotzebue, Gasoline Plant Construction Company; R. P. Mase, Jones & Laughlin Supply Company; P. M. Raigorodsky, Glen Rose Gasoline Company; A. J. L. Hutchinson, Fish Engineering Company; R. B. Cragin, Houdry Process Corporation; in plant operation: E. O. Bennett, consultant, Houston; F. W. Laverty, Clark Bros. Company; R. M. Reed, The Girdler Corporation; J. B. Taylor, Signal Oil & Gas Company; research: R. C. Alden, Phillips Petroleum Company; G. G. Brown, University of Michigan; marketing: J. A. LaFortune, Warren Petroleum Corporation; pipe line transportation: S. S. Smith, Shell Pipe Line Company; cycling: C. R. Williams, The Chicago Corporation.

D. E. Buchanan, Hanlon-Buchanan, Inc., will act as "interlocutor." He will be assisted by a committee, which will divide questions from the audience so they will have consideration from men best fitted for answers. This committee will be Henry M. Brown, Midland Gasoline Company; W. L. Bowser, The Atlantic Refining Company; Phil D. Baker, Carter Oil Company; F. M. Perry, Cities Service Oil Company; Max L. Riley, Anco Gas Company.

Western Refiners Plead Price Restriction Release

Removal of price restrictions on petroleum products was one of the recommendations of Western Petroleum Refiners Association in Fort Worth March 25, 26 and 27. This action by resolution followed a report by B. L. Majewski, Deep Rock Oil Corporation, who also read an outline of the OPA position from J. H. Reppert, associate director, fuel division, OPA, Washington. Along with passing a price-removal plea the association recommended that individual members urge members of Congress to end the OPA price control.

Ernest O. Thompson, member of the Texas Railroad Commission, urged refiners in Texas to make ready for the use of greater quantities of the lighter hydrocarbons, since it is the attitude of the regulatory body to curtail waste of natural gas by flares in the field, a program that will force more lighter materials into manufacturing channels.

Robert Ash, Washington counsel for Prentice-Hall, Inc., analyzed the federal tax program and predicted little change during 1946. He pointed out that, the budget approved will not permit immediate reduction, while some demands will result in additional expenditure.

Conventions

April
17-19—Natural Gasoline Association of America, Baker Hotel, Dallas.
18-19—National Petroleum Association, Hotel Cleveland, Cleveland.
23-25—Southwest Gas Measurement Short Course, University of Oklahoma, Norman.
28—API Directors, Blackstone Hotel, Fort Worth, Texas.

May
7-8—Natural Gas Department, American Gas Association, Hotel Gibson, Cincinnati.
7-9—National Association of Corrosion Engineers, President Hotel, Kansas City.
7-9—Petroleum Industry Electrical Association and Petroleum Electrical Supply Association, Mayo Hotel, Tulsa.

June
24-29—American Society for Testing Materials, annual meeting, Buffalo.

September
16-20—National Instrumentation Conference and Exhibit, Wm. Penn Hotel, Pittsburgh.

November
11-14—American Petroleum Institute, annual meeting, Stevens Hotel, Chicago.

The effect of OPA regulations on the whole of American industry as well as upon the liberties of the American people was stressed by R. R. Wason, Manning, Maxwell & Moore, and president of the National Manufacturers Association.

W. J. Brons, Chicago Journal of Commerce, discussed the debt structure of the country in its relation to business. A. J. Pettigrove, Stanolind Oil & Gas Company, Tulsa, gave a report on the use of oil in the war against Japan.

Two technical programs were a part of the association meeting. The following papers were presented:

"Crude Oil Desalting," F. Duane

H. T. ASHTON
President, Western Petroleum Refiners Association

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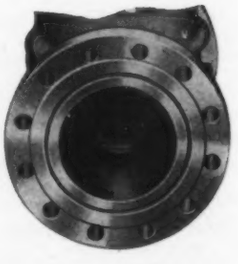

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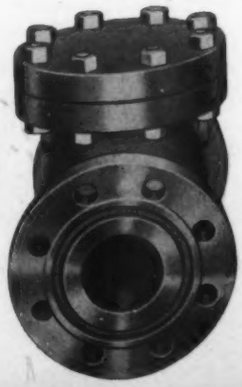

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THE MONTH...

Fuqua, Ben Franklin Refining Company, Ardmore, Oklahoma.

"The New U. O. P. MS Fluid Type Catalytic Cracking United," Davis Reed, Universal Oil Products Company.

"Stainless Steel and Its Application to the Refining Industry," John S. Ewing, Carnegie-Illinois Steel Company.

"Simplicity and Flexibility of Thermofor Catalytic Cracking," K. G. Holdom, Houdry Process Corporation.

H. T. Ashton, Lubrite Division, Socony-Vacuum Oil Company, St. Louis, was elected president.

T. A. Helling, El Dorado Refining Company, was elected a vice president. Other vice presidents, reelected, are R. W. McDowell, Mid-Continent Petroleum Corporation, Tulsa; T. M. Martin, Lion Oil Company, El Dorado, Arkansas; R. L. Tollett, Cosden Petroleum Corporation, Big Spring, Texas. John C. Day, Tulsa, was reelected secretary.

C. A. Miller Heads API Accident Preventions

Charles A. Miller, The Texas Company, Houston, has been named chairman of the American Petroleum Institute's central committee on accident prevention. He replaces J. L. Risinger, Socony-Vacuum Oil Company, New York, D. V. Stroop, of the institute staff, continues as secretary.

In the 15 years the institute has been engaged in accident-prevention work, accident-severity rates in the petroleum industry have been reduced from 2.06 days lost for each 1,000 hours worked to 1.46 days. Fatalities have been reduced from one to each 1,749 workers to one to each 2,545 workers. The accident rate for oil is well below that of the general industrial average.

Members of the committee for 1946 are: J. C. Askam, The Ohio Oil Co., Findlay, Ohio; S. P. Bearden, Warren Petroleum Corporation, Tulsa; J. C. Bernd, Sinclair Refining Company, East Chicago, Indiana; R. W. Black, Standard Oil Co. of New Jersey, Elizabeth; H. W. Boggess, Sinclair Prairie Oil Company, Tulsa; R. S. Bonsib, Standard Oil Co. (New Jersey), New York; C. E. Booz, Gulf Oil Corporation, Port Arthur; J. S. Boylan, Continental Oil Company, Ponca City; A. W. Breeland, Lone Star Gas Company, Dallas; J. H. Brown, Tide Water Associated Oil Company, New York; W. F. Burris, Phillips Petroleum Company, Bartlesville; Alex S. Chamberlain, Ashland Oil & Refining Company, Ashland, Kentucky; R. J. Daugherty, Cities Service Oil Company, Bartlesville; R. E. Donovan, Standard Oil Company of Calif., San Francisco; H. S. Elkins, National Petroleum Association, Washington; A. J. Ferguson, Standard Oil Company of New Jersey, Baton Rouge; Charles Fitzgerald, Sinclair Refining Company, Fort Worth; A. J. Gorand, Sun Oil Co., Philadelphia; J. R. Gordon, Lion Oil Refining Company, El Dorado, Arkansas; J. Thurman Green, Sun Oil Company, Dallas; R. G. Guthrie, Sun Oil Company, Philadelphia; John Hammermann, Jr., Gulf Oil Corporation, Houston; J. P. Hanna, Sinclair Refining Company, New York; Frank Harrison, The Pure Oil Company, Chicago; R. T. Henderson, Standard Oil Company (Ohio), Cleveland; C. L. Hightower, United Gas Pipe Line Company, Sherveport; J. E. Hill, Union Oil Company, Los Angeles; J. M. Ivy, The Carter Oil Co., Tulsa; P. E. Keegan, Shell Oil Company, New York; J. H. Kelley, The Atlantic Refining Company, Dallas; W. I. Kent, Magnolia Petroleum Company, Dallas; L. F. Knox, General Petroleum Corporation, Los Angeles; Oscar B. Lewis, Ethyl Corp., New York; J. W. Lord, The Atlantic Refining Company, Philadelphia; W. E. Lovejoy, Standard Oil Company of California, San Francisco; W. F. Lowe, Natural Gasoline Association of America, Tulsa; H. T. Markee, Phillips Petroleum Company, Bartlesville; A. J. Martinson, California Petroleum Safety Board, Los Angeles; A. M. McKean, Pan American Petroleum and Transport Company, New York; F. R. McLean, Socony-Vacuum Oil Company, Detroit; R. W. Metcalf, Signal Oil & Gas Co., Los Angeles; E. C. Mishou, Interstate Oil Pipe Line Company, Tulsa; E. D. Murphey, Mid-Continent Petroleum Corporation, Tulsa; J. Howard Myers, The Atlantic Refining Company, Philadelphia; Geo. F. Prussing, Western Oil and Gas Association, Los Angeles; I. G. Reed, Tide Water Associated Oil Company, San Francisco; J. L. Risinger, Socony-Vacuum Oil Company, New York; R. B. Roaper, Humble Oil & Refining Co., Houston; Warren A. Sinsheimer, Petroleum Advisers, Inc., New York; Berle H. Swift, Barnsdall Oil Company, Tulsa; C. L. Swim, Skelly Oil Company, Tulsa; E. A. Timm, Standard Oil Company of New Jersey, Bayonne; Frank Werner, American Republics Corp., Houston; W. O. Wilson, Standard Oil Co. (Indiana), Chicago; S. M. Wolbert, Kendall Refining Co., Bradford, Pennsylvania; Karl F. Woodward, Houston Oil Company of Texas, Houston, and W. N. Young, Shell Oil Company, Inc., San Francisco.

Government Selling Ten War-Built Refineries

War Assets Corporation has listed 10 refining units for sale. In addition some butane recovery plants as well as carbon-black facilities are in the list as follows:

Southport Petroleum Company and Republic Oil Refining Company, Texas City, Texas; Eastern States Petroleum Company of Texas, Houston; Crown Central Petroleum Corporation, Pasadena, Texas; two Continental Oil Company refineries, Ponca City, Oklahoma; Wilshire Oil Company, Norwalk, California; Mohawk Petroleum Corporation, Bakersfield, California; Cooperative Refinery Association, Coffeyville, Kansas, and Great Southern Corporation plant, Corpus Christi, Texas, together with butane plants at Driscoll and Agua Dulce.

Four complete and two incomplete carbon-black plants with a total capacity of 125 million pounds also have been placed on the market including:

Cabot Carbon Company, Guymon, Oklahoma, capacity 15,000,000 pounds, with its own gas wells on the site; Columbian Carbon Company, Seagraves, Texas, capacity 15,000,000 pounds, with a 20-inch gas line; Continental Carbon Company, Sunray, Texas, capacity 20,000,000 pounds, with a 16-inch supply line; Charles Eneu Johnson and Company, Monument, New Mexico, incomplete but planned for a capacity of 15,000,000 pounds, with a 14-inch supply line; Panhandle Carbon Company, Eunice, New Mexico, capacity 15,000,000 pounds; and United Carbon Company, Odessa, Texas, incomplete but planned for a capacity of 45,000,000 pounds, with four supply lines, 14, 16, 24 and 21 inches, respectively.

Standard of California Leases Government Refinery

A portion of the government-owned 100-octane plant of Bakersfield, California, has been leased by Standard Oil Company of California, which proposes to operate about a third of the unit. The company will maintain the remainder for Reconstruction Finance Corporation, which retains the right to dispose of the idle portion at any time.

This plant, which was operated by Mohawk Petroleum Corporation during the war, has been declared surplus by RFC. The lease is for a minimum of two years and is subject to cancellation by either party on one year's notice.

West Texas Plans Large Gas Conservation Program

Expenditures in excess of $50,000,000 will be made in West Texas for gas conservation and recovery of natural gasoline. The projects were considered in conference with representatives of the

Trends of Operations and Changes in Stocks

Figures on crude stocks are from Bureau of Mines weekly reports; all others from American Petroleum Institute weekly reports, which are estimates on Bureau of Mines basis.

(All figures in thousands of barrels—add 000)

Trends in Week Ended:	Crude Oil			Gasoline		Gasoil and Distillate		Residual Fuel	
	Production Daily	Runs to Stills Daily	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End
1945:									
January 27	4,727	4,756	221,310	14,957	88,223	4,843	33,561	9,252	51,119
February 24	4,777	4,803	219,351	15,500	95,972	4,958	28,753	9,084	46,713
March 31	4,781	4,677	223,782	14,644	98,758	4,548	26,889	9,184	41,745
April 28	4,805	4,780	223,474	14,633	94,068	4,636	28,273	9,379	39,813
May 26	4,887	4,950	222,831	15,194	89,121	4,667	29,184	9,670	38,548
June 30	4,903	4,999	220,781	15,546	86,472	4,910	32,213	9,077	40,488
July 28	4,930	4,996	218,507	16,106	86,008	4,598	36,071	9,586	42,283
August 25	4,892	4,931	211,813	15,986	84,693	4,960	39,782	9,356	46,201
September 29	4,357	3,812	222,387	11,913	79,552	3,940	43,689	7,047	46,853
October 27	4,273	4,838	224,230	15,530	74,335	5,159	43,472	8,691	45,943
November 24	4,469	4,648	219,363	15,681	83,184	4,802	45,258	8,800	47,474
December 29	4,474	4,729	218,918	14,546	95,205	5,055	36,651	8,765	42,447
1946:									
January 26	4,626	4,553	220,544	13,622	107,737	5,720	29,498	8,411	39,722
March 2	4,726	4,779	229,430	13,871	104,462	5,888	25,148	8,634	38,441
March 30	4,425	4,684	*225,153	13,896	104,715	5,357	28,240	8,738	37,746

* Bureau of Mines, March 23.

THE MONTH . . .

Texas Railroad Commission and the status of the projects indicates that still other facilities will be built.

A community repressuring and natural gasoline plant for the Keystone field will handle 75,000,000 cubic feet of gas daily. Shell Oil Company and associates have selected site for a plant of 30,000,000 daily in the TXL field. In the Slaughter field The Atlantic Refining Company and associates are considering a project to take care of 43,000,000 cubic feet of gas, part of which will be returned to the formation. One fourth of the $20,000,000 scheduled for the Slaughter field will be for field piping in pressure maintenance.

Stanolind Oil & Gas Company has projects under consideration for fields in Hutchinson County, also the Goldsmith field, Ector County as well as in Cedar Lake, North and South Cowden, Foster, Hendrick, Fullerton and Slaughter.

Gulf Oil Corporation is making preliminary surveys for installations in several West Texas areas.

The combined program in West Texas will be instrumental in providing a major part of the 250,000,000 cubic feet of natural gas which the new line of El Paso Natural Gas Company will take from West Texas to California.

Lion Oil Company Building Thermofor Unit at El Dorado

Lion Oil Company has contracted for installation of a Thermofor catalytic-cracking unit licensed by Houdry Process Corporation at its 20,000-barrel-per-day El Dorado, Arkansas, refinery. Construction will be under the auspices of The Lummus Company.

This unit to process 4500 barrels per calendar day of heavy gas-oil charging stocks, will be of the most recent type which embodies simplification of the Thermofor kiln elevator system for handling spent and rejuvenated catalyst as well as a reduction in structural requirements as the result of more compact design.

The unit will utilize gas-oil charging stocks currently being processed in conventional thermal equipment, and will be operated to produce a maximum yield of catalytic base stock for blending into high octane motor fuels. As the result of this type of operation, a high percentage of premium grade burner oil will be produced. Additional enhancement of octane rating of motor fuels produced within the refinery will be realized by conversion of present thermal cracking facilities to reform low-octane straight-run naphthas and low-end-point selective gas-oils.

Additional polymerization unit feed stock that will be made available as the result of the catalytic cracking operation, and which will be supplemented by future selective reforming operations will result in substantially increased production of high blending value poly gasoline and proportional improvement of finished motor fuel quality.

Engineering and construction work pertaining to revision of present thermal cracking facilities, as well as gas concentration and catalytic polymerization units, will be conducted by Lion Oil Company personnel.

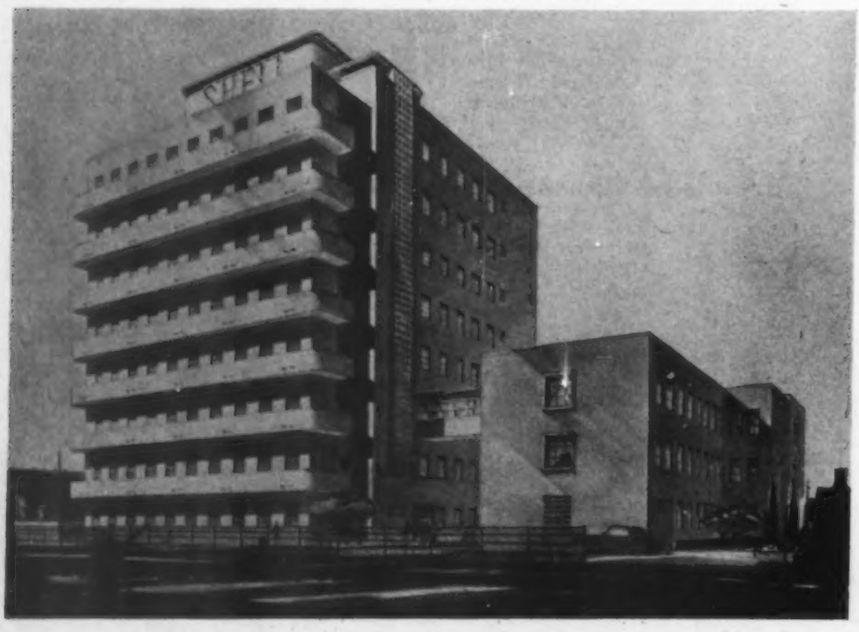
Shell Development Company To Enlarge Laboratory

Expansion of Shell Development Company's research laboratories at Emeryville, California, involving a capital expenditure of more than $3,500,000, has been announced by A. E. Lacomblé, president. Construction will begin this spring and continue over a two-year period. The program includes three major new buildings and extensive remodeling of present facilities. It will permit an increase in personnel from about 600 before the war to an expected 1200 by the time the building program is completed.

Shell Development Company is the central research organization of all "Shell" companies in the United States. General administrative offices are in the Shell Building in San Francisco, together with the engineering and patent departments. Emeryville is across the bay from San Francisco.

The development company was established in 1928, with a staff of 35, and in less than 20 years has grown into the largest research activity on the West Coast.

A. E. Lacomblé is president and director of research, W. J. Hund is manager and associate research director at Emeryville, and O. A. Beeck, K. R. Edlund, T. W. Evans, B. S. Greensfelder, S. H. McAllister, M. W. Tamele and S. Tymstra are associate directors of the laboratories.



Proposed New Shell Development Company Laboratory Building

Sun Oil Company Building 500-Gram Carbon 13 Plant

Sun Oil Company has started work on a 500-gram Carbon 13 plant at its Marcos Hook refinery.

Dr. J. Bennett Hill, manager of the company's research and development division, revealed that much more complicated and involved equipment is needed for production of the rare isotope than for the manufacture of ordinary chemicals, and said a half million pounds of materials must be processed to obtain one pound of C-13.

The new plant is distinguished for a slender shaft 126 feet high, housing four reaction columns. It will produce approximately 12 pounds of C-13 a year, compared with current world production of about half an ounce per year.

Water used in the process must be of such high purity that not only are the minerals removed, but traces of air as well. The catalyst is in the form of 125,000,000 small rings made from 2000 miles of wire. The columns will operate under 250 psi, which must be controlled to a tolerance of not more than 0.1 percent. Special alloys are required for extremely corrosive solutions at high temperatures, and the most critical parts will be glass lined.

Carbon 13, differing from ordinary carbon in that it contains an extra neutron in the nucleus of the atom, has been found to have great value in probing the secrets of cell growth, both normal and diseased, and is being used in studies of metabolic disease processes, such as cancer, diabetes, hardening of the arteries and heart trouble.

Dr. A. V. Grosse, who instigated and carried on C-13 experiments originally; Dr. Sidney Weinhouse of Houdry Process Corporation, and Dr. Stanley P. Reimann, director of Lankenau Hospital Research Institute and the Institute for Cancer Research, who have cooperated in application of C-13 to biological research, and Dr. Allen F. Reid, who developed the special catalyst, were among those attending the ground-breaking ceremonies.

Frank C. Fowler Joins Staff Of University of Oklahoma

Dr. Frank C. Fowler has accepted appointment as assistant professor of chemical engineering at University of Oklahoma, it is announced by W. H. Carson, dean of the College of Engineering. Dr. Fowler's work will be under direction of Dr. R. L. Huntington, director of the School of Chemical Engineering, and his time will be spent in teaching, research and consulting.

Dr. Fowler took his undergraduate

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THE MONTH . . .

DR. F. C. FOWLER

work at the University of Illinois and completed his masters and doctor of philosophy degrees at the University of Michigan. For the past three years he has been employed in the chemical products department of Phillips Petroleum Company.

Miller Returns to Shell at Houston After War Service

John L. Miller has returned to his position as superintendent of operations at Shell Oil Company's Deer Park (Houston) refinery after 44 months of continuous army service outside the country. P. E. Hurley, who has been acting superintendent during Miller's absence, now is manager of the company's Norco, Louisiana, refinery.

JOHN L. MILLER

Miller started with the Shell organization as a gauger at Wood River refinery in 1920. He worked up through the ranks of the manufacturing department, being made successively assistant head stillman, assistant superintendent, and superintendent at other plants before he was transferred to Houston in 1937.

In March, 1942, he was commissioned a major and reported to Washington. Immediately he was sent to Melbourne, Australia, headquarters of the Army Service of Supply, where he was put in charge of all petroleum supplies for the Army ground forces, a post which he held until 1944. At that time he was made chief procurement officer in the Office of the General Purchasing Agent for the Southwest Pacific area, which handled supplies for the Army, Navy and Air Forces.

Field Elected Director of Atlantic Refining Company

Hugh W. Field, assistant manager of the research and development department of The Atlantic Refining Company, Philadelphia, has been elected a director of the company.

Field joined the company as a junior chemist in 1928 shortly after his graduation from the University of Pennsylvania with a B. S. in chemical engineering. He was successively junior engineer, assistant engineer, senior engineer and supervisory engineer until 1940 when he was named assistant manager in research and development.

HUGH W. FIELD

During the war Field acted as a member of or as technical adviser to a number of government committees concerned with development of aviation gasoline. He is general chairman of the convention committee of the American Institute of Chemical Engineers, which will hold its 1946 convention in Philadelphia, and is a member of the American Chemical Society.

Russell Joins Louisiana State University Faculty

George F. Russell, Jr., associate professor of petroleum engineering, is a recent appointee to the engineering faculty at Louisiana State University, Baton Rouge, where he is in charge of the natural gas section of the petroleum engineering department. In addition to his teaching duties, he is doing private consulting on plant design and technical service on special problems. Before joining the university, he had been a member of the chemical technical service staff of Standard Oil Company of New Jersey, a member of the chemical engineering faculty of the University of Oklahoma, and in the natural gas and gasoline department of Phillips Petroleum Company.

Russell received both the bachelor and master of chemical engineering degrees from the University of Oklahoma. He is a registered professional engineer in the fields of natural gas, chemical, and petroleum engineering.

Montgomery Gets Higher Post With Indiana Company

S. A. Montgomery has been promoted to assistant general manager of manufacturing of Standard Oil Company (Indiana) and will be in the Chicago general office. He has been succeeded as manager of the Whiting refinery by Dr. W. J. McGill, who has been superintendent at Wood River refinery. Dr. G. F. Ordeman, assistant general superintendent at Whiting, has been promoted to succeed Dr. McGill, and A. F. Endres, superintendent of the light oils division at Whiting, has been promoted to succeed Dr. Ordeman.

Montgomery joined the company in 1919 as a chemist at Wood River. After serving as assistant superintendent of the paraffine department, superintendent of the lubricating and paraffine department, and as assistant general superintendent, general superintendent, and manager of the refinery, he was transferred to Whiting as manager in 1942. Montgomery was graduated from Mis-

S. A. MONTGOMERY

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Negligible stray light effects assure increased accuracy.

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It is the continuing aim of National Technical Laboratories to produce instruments which combine the best previous achievement with unique developments which further extend the application of instruments in industry. The IR-2 Spectrophotometer again attains this goal. It integrates well-known basic principles of optics with new developments in electronic circuit design, many of which originated in our own laboratories in the production of thousands of scientific instruments. The result is an Infrared Spectrophotometer with increased convenience and versatility that greatly extend the usefulness of infrared methods.

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sissippi State College and served in the chemical warfare service during World War I.

Dr. McGill joined the company in 1924 as a chemist at Whiting. In 1928 he was transferred as lubricating works assistant to Wood River, where he became general foreman of the lubricating works and assistant general superintendent and then general superintendent of the refinery before being promoted to manager in 1942. Dr. McGill is an alumnus of the University of Michigan.

Dr. Ordeman became associated with the company in 1919 as a chemist at Whiting. After serving as assistant superintendent of the asphalt and acid department he entered the light oils division where he was successively head of the finishing, crude still, and pressure still departments and superintendent of the light oils division. He was promoted to assistant general superintendent of the refinery in 1943. Dr. Ordeman is an alumnus of Washington and Lee and Johns Hopkins universities and was a first lieutenant in World War I.

Endres joined the company in 1923 as a chemical engineer at Whiting. He was assigned to the light oils division as head of the finishing department and after serving also in the crude still and pressure still departments and as assistant superintendent of the division was advanced to superintendent of the light oils division in 1943. He was graduated from the University of Illinois.

Sun Oil Company Announces Refinery Personnel Changes

Donald Lincoln has been appointed manager of the refinery supply and distribution division of Sun Oil Company, it was announced by Arthur E. Pew, vice president. Lincoln formerly was manager of the refinery production control division. He has been with the company since 1930.

Clifford Johnson has been made assistant superintendent of the company's Marcus Hook refinery, in charge of maintenance and construction. He formerly was superintendent of maintenance, and in his new position succeeds Alan T. Knight who has been elected vice president of Catalytic Engineering and Construction Company, recently organized to engage in the design and construction of oil refineries and oil-refinery equipment.

DONALD LINCOLN

CLIFFORD JOHNSON

John E. Lilley, formerly project engineer, has been appointed chief construction engineer at Marcus Hook refinery, and Vaughn S. Whitesell, formerly maintenance engineer, has been appointed chief maintenance engineer. Howard B. Sheppard has been promoted to project engineer in the manufacturing department.

A. Cyril Daldy, former assistant director of foreign refining, Petroleum Administration for War, has joined the public relations staff of Sun Oil Company.

Name Advisory Committee For Synthetic Liquid Fuels

Through an advisory technical committee of 11 members the United States Bureau of Mines has made provision for keeping close contact with industry in the development of its synthetic-fuels program. Concerning their selection Dr. R. R. Sayers, director of the bureau, said:

"The cooperation and technical guidance of these men, all of whom are authorities on industrial petroleum and coal research, will be of invaluable assistance in attaining the objectives of the bureau's five-year synthetic liquid fuels research and development program. At the same time the information on the bureau's work will be disseminated and a liaison will be maintained with industrial concerns which ultimately may develop commercially the processes under study."

Committee members are Eugene Ayers, Gulf Research and Development Company; George Creelman, Pittsburgh Consolidated Coal Company; Fred Denig, Koppers Company; H. W. Field, The Atlantic Refining Company; H. O. Forrest, The M. W. Kellogg Company; Dr. Louis S. Kassel, Universal Oil Products Company; L. C. Kemp, Jr., The Texas Company; E. V. Murphree, Standard Oil Development Company; J. K. Roberts, Standard Oil Company (Indiana), and Dr. Harold J. Rose, Bituminus Coal Research, Inc.

Associated Division Makes Personnel Changes

Several changes in the organization of the manufacturing department of Associated Division of the Tide Water Associated Oil Company, San Francisco, recently have been announced.

Following successful completion of the war program of the manufacturing department, Lloyd F. Bayer, vice president, who headed that department during the war years, has returned to his former full-time duties as chairman of the operating committee.

For more than 16 years general supervisor of the research and development department, Herschel Y. Hyde, has been appointed vice president in charge of manufacturing. Hyde, a graduate of the University of California and Massachusetts Institute of Technology, has been with the company since 1928.

C. K. Viland has been appointed general supervisor of the research and development department, succeeding Hyde.

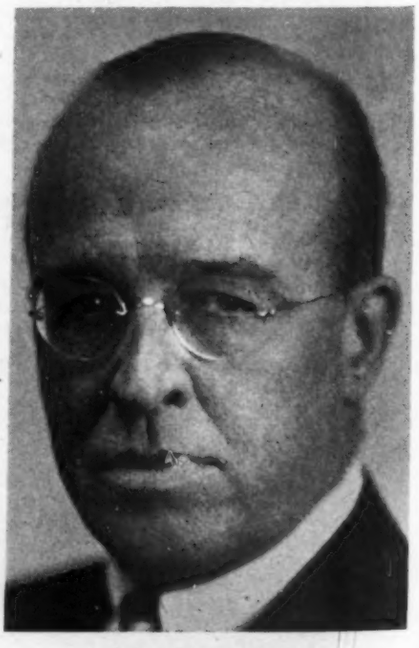
W. P. Hugo, who continues as manufacturing manager, was appointed an assistant vice president of the company.

T. O. Edwards, Jr., general superintendent of Avon refinery for more than eight years, has been appointed general manager of that plant.

Company to Specialize On Houdry Processes

Formation of Catalytic Engineering and Construction Company to engage in design and construction of oil refineries and oil-refinery equipment was announced March 7 by T. Ellwood Webster, president of the new company.

Webster, formerly assistant to the



F. ELLWOOD WEBSTER

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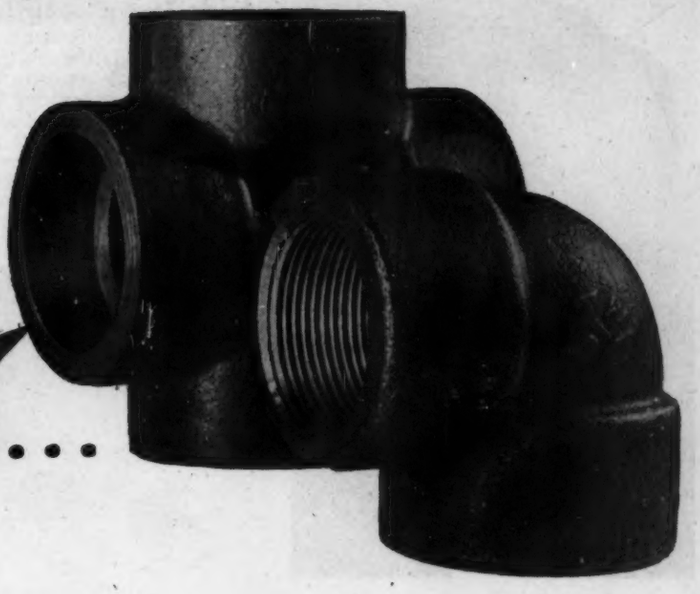

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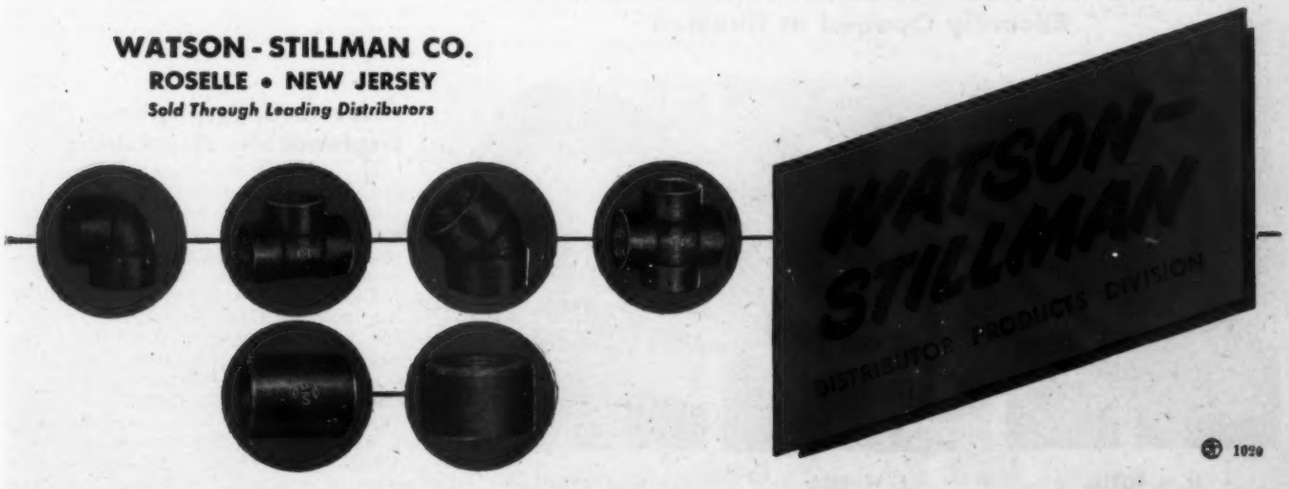

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THE MONTH . . .

ALAN T. KNIGHT

president of Sun Oil Company, said the new company will specialize in the design and construction of catalytic refinery units employing processes licensed by Houdry Process Corporation, of both the fixed-bed and Thermofor moving-bed types.

Alan T. Knight, formerly manager of maintenance and construction at Sun Oil Company's Marcus Hook refinery, is vice president of the new company, which was recently incorporated in Delaware. W. Graham Jamison is secretary-treasurer, and Vernon L. Stover is assistant secretary. Jamison was formerly chief accountant in the general accounting department in charge of petroleum compensatory adjustments for Sun Oil Company.

Directors of the new company are Webster; Knight; Arthur E. Pew, Jr., vice president of Sun Oil Company in charge of manufacturing and research; Clarence H. Thayer, chief engineer and a director of Sun Oil Company; Robert G. Dunlop, comptroller and a director of Sun Oil Company.

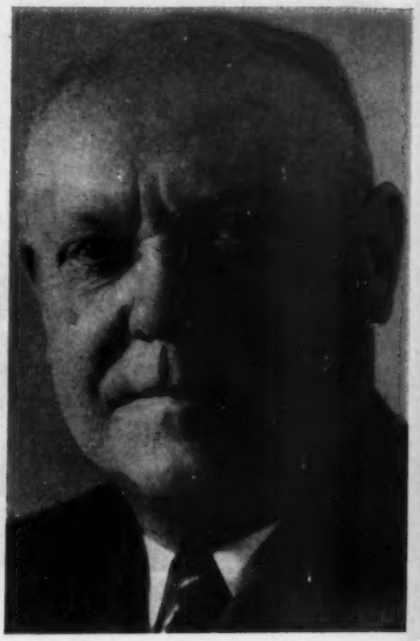
M. W. Kellogg Company Adds Two Executive Officers

The M. W. Kellogg Company recently elected the following officers: M. W. Kellogg, chairman of the board; H. R. Austin, president; F. E. Johnson, vice chairman of the board, and L. H. Harvison, executive vice president. Creation of the executive positions of chairman and vice chairman of the board, it was explained, was necessitated by the company's proposed expanded program

L. H. HARVISON

of industrial engineering, manufacturing, and process development. Petroleum engineering will continue a major part in the company's activities, and services to other process industries which has increased markedly in recent years, will be further developed.

The plans for widening the base of the company's operations also provide for extended study of the commercial possibilities of the new processes, equipment and materials developed in connection with its work on the atom-bomb



H. R. AUSTIN

project, at Oak Ridge, Tennessee, as well as utilizing the metallurgical and fabricating advances achieved at the company's plant and laboratories at Jersey City, New Jersey.

The M. W. Kellogg Company was founded in 1905, and operated as a privately-owned enterprise until December 1944 when control of the company was purchased by Pullman, Inc. The present election marks the first major change in executive personnel since the company was formed.

The history of the company is in effect a history of petroleum and chemical engineering development. Rising from a modest foundry business which concentrated first on piping and chimney construction, the company turned to building Burton still shells; and, with increased laboratory research and experiment in process development, the company became a pioneer in the growth of the oil-refining industry. Expansion and wider activity continued, carrying the company into international fields where it won recognition both in petroleum and in related engineering, and in process development.

Head Brown & Root Petroleum Construction Division Recently Opened at Houston

M. H. ROTHS
Manager

F. W. BELL
Process Engineer

H. M. ANDERSON
Engineer

Elder and Armitage Engineering Associates

H. D. Armitage recently joined with A. M. Elder to form Elder and Armitage, for the purpose of doing chemical plant process and mechanical engineering, with offices at 736 Bankers Mortgage Building, Houston.

Elder has been operating an engineering office in Houston for the past year. He is a graduate in mechanical engineering from Iowa State College and the United States Naval Academy, and has been employed as engineer by Converted Rice, The B. F. Goodrich Company, Standard Oil Company of California, and Natural Gas Pipeline Company of America.

Armitage received a B. A. degree in

NO WASTE TO BE BURNED!

SHELL'S New Cycling Plant

An outstanding feature of Shell Oil Company's new cycling plant at Sheridan, Texas, is the elimination of flare gas in all operations and consequent avoidance of waste.

With a rated capacity of 100,000,000 cu. ft. of condensate gas daily, the new Sheridan Plant returns gas to the sand at a pressure of approximately 4350 lbs. per sq. in. The plant operates at 1800 lbs. suction pressure.

The compressor installation consists of seven 800 HP Clark "Angle" Compressors. One of these is devoted entirely to recompression service and there is one recompression cylinder on each of two other units.

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THE MONTH...

chemistry in 1934 and a B. S. in chemical engineering in 1936, both from the University of Oklahoma. Lately he was process engineer with Arthur G. McKee & Company, and previously was with The B. F. Goodrich Company and Gulf Oil Corporation in a similar capacity.

Fisher and Old Join Arthur D. Little Staff

Dr. Austin W. Fisher and Dr. Bruce S. Old have joined the staff of Arthur D. Little, Inc., Cambridge, Massachusetts.

Dr. Fisher, a graduate of Massachusetts Institute of Technology and of

DR. BRUCE S. OLD

Massachusetts State College, formerly was with Barrett Division of Allied Chemical and Dye Corporation and with Publicker Industries, Inc. He will supervise chemical engineering research.

Dr. Old graduated from University of North Carolina and from Massachusetts Institute of Technology. He previously was with Bethlehem Steel Company and, as a commander in the Naval Reserve, was associated with wartime technical development for the Navy. He now will engage in metallurgical research.

Anderson-Prichard Oil Corporation Reorganized

Anderson-Prichard Oil Corporation, Oklahoma City, has completed reorganization of its corporate setup following retirement of P. H. Anderson, vice president and treasurer, and J. Steve Anderson, Jr., service agent, from the organization, and sale of a substantial stock interest to the public. The sale to the public included 80,000 shares of 4¼ percent $50-par preferred and 425,000 shares of $10 common. The latter is 68 percent of the common, the balance being retained by L. H. Prichard, Sr., who continues as president.

New officers, in addition to the president are T. H. Marshall, vice president,

DR. A. W. FISHER

treasurer, finance officer and director; L. H. Prichard, Jr., director; Dr. R. W. Brauchli, in charge of land and geological department; George H. Burruss, in charge of refining; C. H. Dresser and C. L. Mayhall, marketing; Weston Payne, in charge of crude oil purchasing; C. A. Prichard, in charge of materials purchase and traffic; D. R. Grable, secretary; and Neale Boyd, Roy Winters and S. A. Garrison, assistant secretaries and treasurers. Arthur D. Chilgren and Charles F. Glore, both of Chicago, are added to the directors.

Walter Miller Retained As Universal Consultant

Dr. Walter Miller, who retired on March 1 as vice president in charge of manufacturing for Continental Oil Company, has been retained by Universal

DR. WALTER MILLER

Oil Products Company as a consultant on refining techniques and operations.

Dr. Miller has been actively associated in the refining industry since 1909, and is recognized as an authority on refining operations. In his new connection, according to the company's announcement, he will be available for consultation on problems affecting addition or modernization of refinery equipment by Universal Oil Products Company's licensees.

Du Pont Company Plans Nitric Acid Investigation

Plans to investigate organic syntheses involving nitration, nitrolysis, nitric acid esterification, and nitric acid oxidation to provide new and useful compounds for industry are announced by E. I. du Pont de Nemours & Company. A program for large-scale semi-works production of new organic derivatives already is under way in the explosives department.

The compounds include the new cyclohexane derivatives—epsilon-caprolactam, cyclohexanone oxime, and nitrocyclohexane.

Du Pont said the lactam and the oxime can be supplied in quantities ranging from pound lots for laboratory and semi-commercial scale work to ton lots for industrial applications for use in textile processing, the pharmaceutical industry, or in the manufacture of corrosion inhibitors, insecticides, etc.

Pound samples of nitrocyclohexane are available for experimental use in the manufacture of rubber chemicals, resins, solvents, dyes, pharmaceuticals, lacquers, and emulsions. Among its possibilities is use as an industrial solvent in the dewaxing of lubricants and the extractive distillation of petroleum, the company said.

Epsilon-caprolactam is available either as a solid or as a 67-76 percent aqueous solution. It can be readily hydrolyzed to give epsilon-aminocaproic acid, which has been suggested as a starting material for the synthesis of alpha, epsilon-diaminocaproic acid (synthetic lysine), as a nutrient and promoter for the growths of yeasts; and as an ingredient in the preparation of more complex proteins and gels. The vinyl derivative of epsilon-caprolactam is said to have value as a textile assistant, plasticizer, etc. Caprolactam can be chlorinated, sulfonated, methylated, etc., to produce new and interesting derivatives.

Properties:

Melting point	68.5° C. minimum
Boiling point at 10 mm. Hg	136-138° C.
pH (40% aqueous solution)	4.0-6.0

Very soluble in water, acetone, ethanol, benzene, and chloroform. Slightly soluble in ether and in carbon tetrachloride.

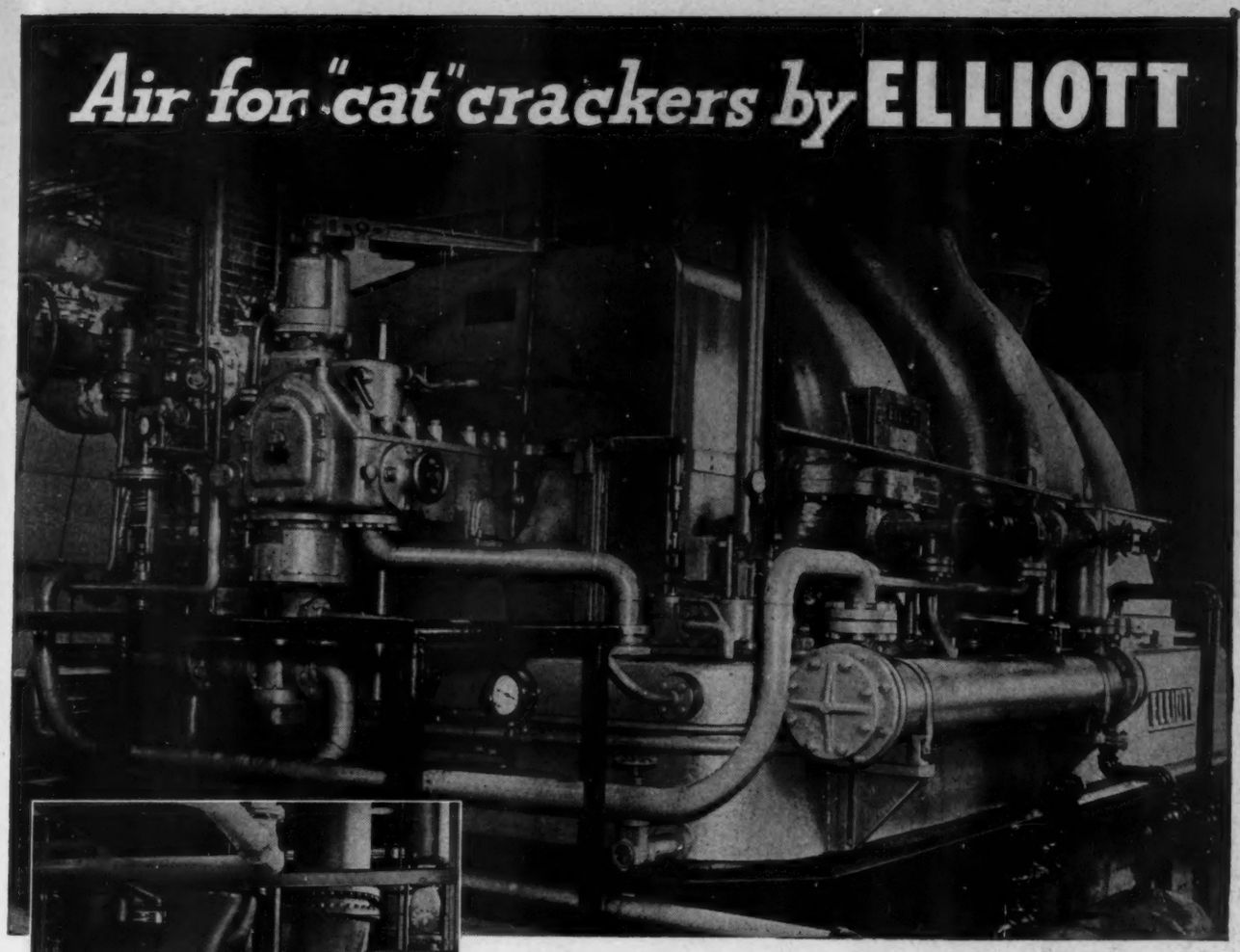
Cyclohexanone oxime is available as a white crystalline solid. As a ketoxime of cyclohexane it is an important intermediate in organic reactions involving synthesis of cyclohexyl derivatives.

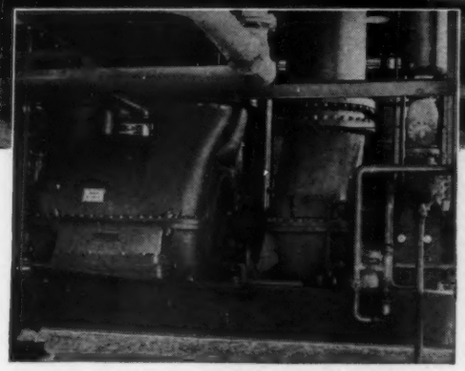
Properties:

Melting point	88.5° C. minimum
Boiling point at 760 mm. Hg	206-210° C. (with slight decomposition)
Boiling point at 10-12 mm. Hg	100-105° C.
Vapor pressure at 43.5° C.	0.1 mm. Hg
Purity	99.9% minimum

Nitrocyclohexane is available in lots up to five gallons for experimental purposes. It undergoes the reactions typical of the nitroparaffins and thus opens up a path to a wide variety of new organic compounds, including nitro and amino alcohols, acids, and esters. It can be

Air for "cat" crackers by ELLIOTT





The large photo shows an Elliott turbine-driven blower in "cat" cracking service at a mid-western refinery. This blower has a capacity of 50,000 cfm free air, discharging at 15 psi gage. It is driven by an Elliott 3500-hp turbine.

The smaller photo shows an installation in a Pacific coast refinery. It is one of the largest turbo-blowers in "cat" cracking service. The blower is a multi-stage type with a capacity of 55,000 cfm, discharging at 15 psi gage. It is driven by an Elliott 4500-hp steam turbine.

"CAT" CRACKING has called for many Elliott centrifugal blowers to furnish the large quantities of air required to reactivate the catalyst. Shown here are two of the larger turbine-driven units in plants that have turned their energies from the production of wartime high octane to supplying the civilian demand for the "new" gasoline that is stepping up the power and flexibility of America's weary auto engines.

Elliott centrifugal blowers are particularly adapted to "cat" cracking service by their smooth, quiet, vibrationless performance and their capacity for dependable, uninterrupted operation. Blowers are available with either turbine or motor drive, the entire unit being Elliott-built. Ask us for full details on Elliott blowers. If you have a blower problem, use the experienced cooperation of the Elliott blower engineer in your district.

ELLIOTT BLOWERS

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P-1072

The heart of the "cat" cracker

THE MONTH...

hydrogenated at moderate temperature and pressure to form cyclohexylamine which may be used as an intermediate in the production of corrosion inhibitors, insecticides, solvents, plasticizers, etc.

Properties:

Boiling point at 760 mm. Hg	203-204° C. (with slight decomposition)
Boiling point at 40 mm. Hg	109° C.
Boiling point at 20 mm. Hg	94° C.
Freezing point	—34° C.
Specific gravity at 25/25° C	1.0630
Pounds per gallon at 77° F	8.8
Flash point (open cup)	180° F.
Miscible with acetone, alcohol, benzene, cyclohexane, ether, and kerosine.	
Solubility in water at 25° C	0.15%

The company said its explosives department, with adequate semi-works facilities and a broad background in the evaluation of processes employing nitric acid, would welcome requests for the manufacture of any new compounds which may fall within the scope of this program.

Sonneborn Names Two Technical Aides at Petrolia

Dr. Henry Sonneborn III, until recently a lieutenant in the Navy, and Dr. Hans Schindler, research chemist, have joined the technical staff of the Petrolia, Pennsylvania, refinery of L. Sonneborn Sons, Inc.

A graduate of Johns Hopkins University, where he received his Ph.D. in chemistry, Dr. Sonneborn returns to the company as assistant to Dr. F. W. Breth, vice president and technical director. He had held that position prior to his service during the past four years as experiment and test officer at the Naval Ammunition Depot, St. Juliens Creek, Virginia.

Dr. Schindler joins the company as a research chemist with headquarters at the Petrolia refinery. Formerly senior research chemist at the research and development laboratories of the Pure Oil Company, Winnetka, Illinois, he recently served as a member of the technical oil mission which investigated the German petroleum industry for the technical industrial intelligence committee.

MISS ALICE C. BARTLES

Miss Bartles Made Officer of Standard Oil Development

Miss Alice C. Bartles has been named assistant secretary of Standard Oil Development Company, and as such shares responsibilities of administration of the company and the handling of contracts, patents and other records. She started with the company 13 years ago as a typist, and since 1943 has been assistant to R. W. Burkhart, secretary of the company.

The first woman to be an executive officer of Standard Oil Development Company, Miss Bartles is the third advanced to such status in companies of the Standard Oil Company (New Jersey) group within the past six months. Previously, Miss Muriel E. Reynolds and Mrs. Margery M. Porter were appointed assistant secretaries of the parent company.

January Daily Average Imports Sets New High

January imports of crude oil and refined products totaled 12,806,000 barrels, an increase of almost 25 percent over the 9,919,000 barrels imported in December, the Department of Commerce reported. The daily average of 413,000 barrels was the highest ever recorded.

Crude-oil imports totaled 8,302,000 barrels, or 268,000 barrels per day, and refined products amounted to 4,504,000 barrels, or 145,000 barrels daily, the figures showed. Refined receipts included 3,878,000 barrels of residual fuel oil, 581,000 barrels of distillate fuel oil, and 45,000 barrels of asphalt.

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HAMER PLUG VALVES NEVER STICK!
Under the toughest service conditions—extremes of temperature, handling viscous, sticky fluids—Hamer Plug Valves always operate instantly, no matter how long the interval between operations. That's because the plug adjusting nut under the plug head gives positive turning under all conditions . . . an exclusive Hamer feature.
Hamer All-Steel, Flanged, Balanced Type Plug Valve. Bar operated. 600 lbs. Working Pressure; 1200 lbs. Test Pressure. Suitable for varied industrial services where a lubricated or non-lubricated valve is required.
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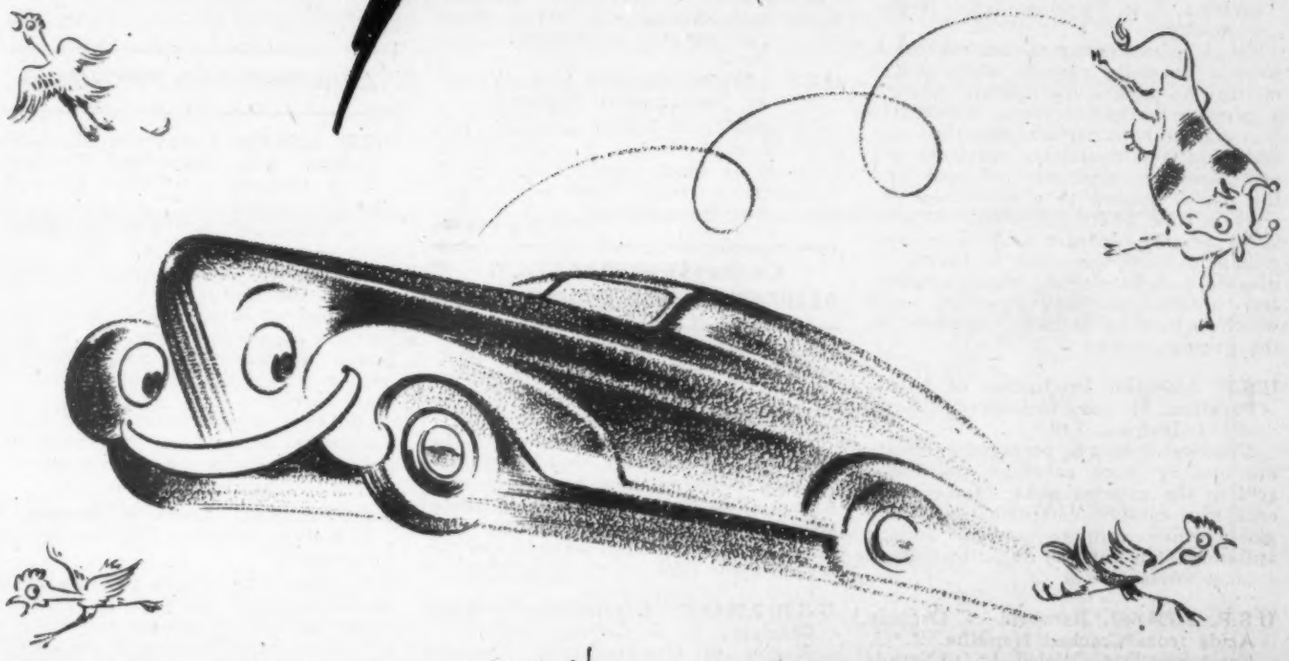

Refiners of high octane gasoline meeting today's demand for super-power find SOLVAY Caustic Potash is manufactured with a minimum of impurities and suited to their needs.

In producing your high octane gasoline, depend on SOLVAY's exacting quality.

- SOLVAY Caustic Potash Liquor (shipped in tank cars) has a KOH content of 49 to 50%.
- SOLVAY Caustic Potash in the *dry* form contains a minimum of 90% KOH.
- No matter what your needs—liquid, solid, or flake, SOLVAY can deliver promptly.

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Shipped in tank cars—10,000 gallons

★ **SOLID** 90% minimum KOH
Shipped in 700 lb. steel drums

★ **FLAKE** 90% minimum KOH
Shipped in 350 lb. steel drums

Digest of Recently Issued United States

Patents Pertaining to Petroleum Refining

Compiled by HEINZ HEINEMANN

REFINING

U.S.P. 2,393,895. Treatment of Hydrocarbons. J. R. Fleming to The Texas Company.

Ethylene and propylene are separated from a normally gaseous hydrocarbon mixture by passing the mixture through a primary extraction zone wherein it is contacted with partially desorbed sulfuric acid. Gas containing ethylene- and propylene-rich acid are removed and the gas is passed to a secondary extraction zone where it is contacted with 90-94 percent sulfuric acid. Ethylene-rich acid from this zone is heated to liberate a major portion of the ethylene and produce partially desorbed acid which is used as extraction medium in the primary zone.

U.S.P. 2,394,315. Production of Nitro-Paraffins. M. Levy to Imperial Chemical Industries, Ltd.

Nitro-paraffins are prepared by heating one or more paraffins and nitric acid in the gaseous phase in the presence of a catalyst comprising a silicate glass which contains arsenic and/or antimony. The catalyst ought to present a large surface area.

U.S.P. 2,394,662. Removal of Organic Acids from Cracked Naphtha. E. Q. Camp and D. C. Walsh, Jr., to Standard Oil Development Company.

Cracked naphtha is processed by feeding it to distillation equipment and recovering an overhead fraction which is then scrubbed with caustic. Spent caustic is contacted with feed stock to the distillation equipment to remove corrosive constituents.

U.S.P. 2,394,978. Refining Process. R. C. Brandon to Standard Oil Development Company.

A petroleum fraction is extracted with caustic soda, phenols in the extract are precipitated with CO_2 or mineral acids and precipitated phenols are catalytically cracked at 800-1000°F. and under approximately atmospheric pressure. The cracked phenols are used as oxidation inhibitors in gasoline.

U.S.P. 2,395,022. Aluminum Halide Hydrocarbon Conversion System. M. Sutton and C. W. Nysewander to Standard Oil Company (Indiana).

A liquid hydrocarbon stream flowing from a reaction zone and containing a hydrogen halide and uncombined aluminum halide is treated with a normally liquid, complex forming olefin-free hydrocarbon. A readily separable complex is formed and introduced into the reaction zone.

U.S.P. 2,395,362. Separation of Hydrocarbons. C. E. Welling to Phillips Petroleum Company.

A gaseous mixture containing ethane, ethylene and acetylene is separated by preferential absorption of ethane and acetylene in a high-boiling paraffin oil at 25-150°F. and under 800 psi pressure. The extracted oil is subjected to liquid-liquid extraction with a solvent selective for unsaturated hydrocarbons.

U.S.P. 2,395,382. Gasoline. E. L. Walters to Shell Development Company.

The stability of leaded saturated gasoline type motor fuels is increased by the addition of small amounts of both 2, 4-dimethyl-6-tertiary butyl phenol and alkyl phenylene diamine.

CATALYST PREPARATION ACTIVATION AND REGENERATION

U.S.P. 2,393,893. Method and Apparatus for Hydrocarbon Conversion. L. P. Evans and F. E. Ray to Socony-Vacuum Oil Company.

The invention has for its object the provision of method and apparatus wherein a complete and uniform utilization of all the portions of the flowing stream of a contact mass material may be attained in both the reaction and the regeneration zone.

U.S.P. 2,394,680. Regeneration of Spent Catalyst. C. G. Gerhold and L. A. Mekler to Universal Oil Products Company.

The invention is concerned with the regeneration of fluid catalysts. It differs from the conventional operatoin in that catalyst particles and regenerating gases pass countercurrently through the regeneration zone. The catalyst first comes in contact with hot combustion products in the upper portion of the regenerating zone and a considerable quantity of vaporizable hydrocarbons is vaporized rather than oxidized.

U.S.P. 2,394,796. Hydrocarbon Conversion. M. M. Marisic to Socony-Socony-Vacuum Oil Company.

A cracking catalyst is prepared by impregnating porous active alumina with ethyl silicate and hydrolysing the silicate within the porous alumina structure. The molar ratio of silica to alumina should be between 1:4 and 1:20.

U.S.P. 2,395,048. Catalytic Treatment of Hydrocarbons. R. R. Hibbard to The Standard Oil Company (Ohio).

Useful catalysts for the reforming, aromatizing, desulfurizing or cracking of hydrocarbons in the presence of hydrogen at 850-1200°F. are prepared by reacting an organic reducing agent with CrO_3 in a slurry of aluminum hydroxide.

U.S.P. 2,395,291. Catalyst. R. J. Patterson to Phillips Petroleum Company.

A mixture of $AlCl_3$ and metallic aluminum (0.02 to 5 percent) is molten under 10-300 psi pressure and enough HCl gas passed into the melt to convert some aluminum to $AlCl_3$. The liberated hydrogen produces a porous spongy mass which is rapidly cooled and solidified.

CRACKING AND REFORMING

U.S.P. 2,393,636. Conversion of Hydro carbons with Suspended Catalysts. E. A. Johnson to Standard Oil Company (Indiana).

The invention deals with the catalytic cracking of dirty stocks without experiencing difficulties from excessive catalyst contamination. The heavy hydrocarbon oil is introduced into a heating and vaporizing zone and is there heated to conversion temperature by contact with a hot, granular refractory heat carrier. The vapors then are passed to a catalyst zone, while the carbonaceous deposits on the refractory material are burned off at intervals.

U.S.P. 2,394,617. Chemical Process. P. E. Kuhl to Standard Oil Development Company.

A process to reform naphtha is described in which the naphtha is at first contacted with a catalyst consisting of a metal of the sixth group of the periodic table under conditions of elevated temperature and pressure and in the presence of externally supplied hydrogen. After a while the hydrogen supply is discontinued and the process is operated with a net production of hydrogen which decreases as the operation proceeds. Hydrogen produced is recycled.

U.S.P. 2,394,654. Conversion of Hydrocarbons. R. T. Bell, H. O. Folkins and C. M. Thacker to The Pure Oil Company.

The cracking of hydrocarbons can be accelerated by the addition of oxy-halogneated aliphatic compounds such as ethylene bromohydrin, chloral, dichloroacetylchloride, etc. Between 0.25 and 3 mole percent of the sensitizer are preferably used.

U.S.P. 2,395,081. Cracking and Coking Hydrocarbon Oils. T. Williamson and N. A. Scardino to The Texas Company.

A process is described in which oil is heated to a cracking temperature and directed to a reaction zone wherein it is subjected to cracking conditions of temperature and pressure and wherein separation of vapors from liquid residue takes place and in which the liquid residue together with a portion of the vapors sufficient to effect coking is flash distilled to a coke residue, while the remaining vapors are separately withdrawn from the reaction zone and di-

Modernize?

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1 to 75 hp
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Speeds from 1430 to 7½ rpm

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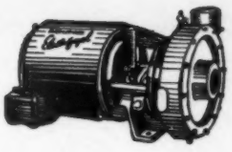
V-belts — Section A B C D E
Oil resisting
Heat resisting
Static resisting
Oil-proof
Super-7 steel
Sheaves
Constant ratio — ½ to 6000 hp
Variable ratio — 1 to 300 hp
Magic Grip — 2 to 250 hp
Speed changers — 1½ to 75 hp



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Single and Double Suction
Horizontal and Vertical
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Self Priming | Pipe Line
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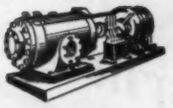
AXIAL FLOW
Horizontal and Vertical

MIXED FLOW
Horizontal and Vertical

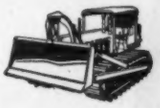
Centrifugal and Axial Blowers

Single Stage { 1 to 6.25 lb G.; 600 to 100,000 cfm
Multi Stage { 1 to 50 lb G.; up to 130,000 cfm
All ratings are based on atmospheric inlet pressures.



Sliding Vane Compressors and Vacuum Pumps

Compressors { 5 to 35 lb G.; 50 to 1600 cfm
Vacuum pumps { up to 28½" hg; 15 to 2000 cfm



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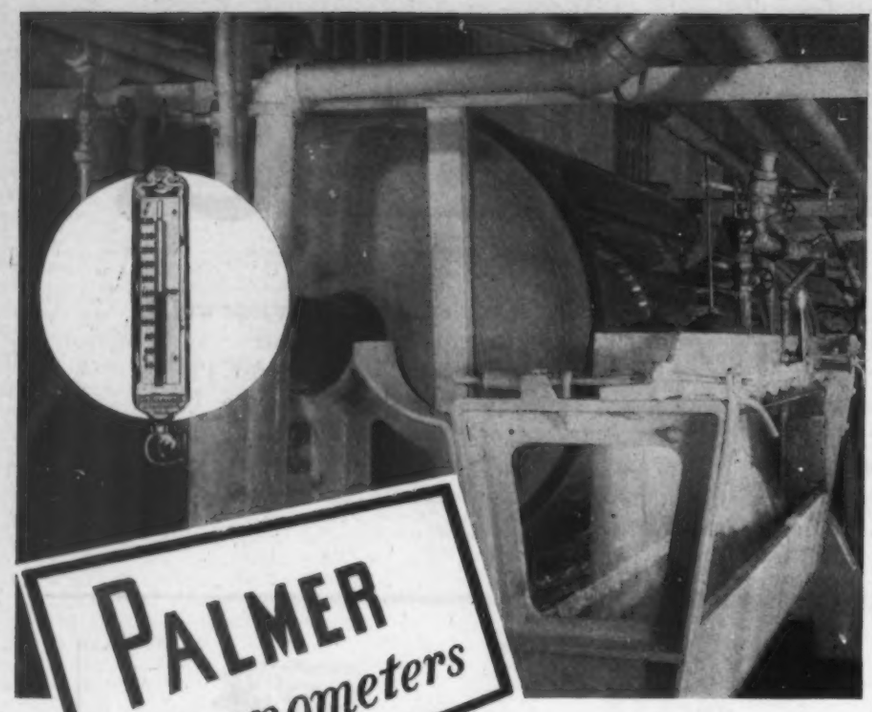

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THE PALMER COMPANY

rected to a zone separate and apart from the coking zone.

U.S.P. 2,395,153. Catalytic Cracking. C. L. Thomas and J. E. Ahlberg to Universal Oil Products Company.

Alumina-silica cracking catalysts are rendered more stable for long periods of use when the originally precipitated hydrated silica is substantially free of alkali metal ions. The precipitated silica is washed with an aqueous solution of a compound having a cation capable of replacing alkali metal ions. The purified silica is commingled with an aluminum salt solution and aluminum oxide is deposited on the silica by hydrolysis of the aluminum salt.

ISOMERIZATION

U.S.P. 2,392,798. Normal Butane Isomerization. Louis D. Kleiss to Phillips Petroleum Company.

A first portion of n-butane is passed into a low point of a reaction zone containing a previous bed of solid packing material for upward flow through the bed. An $AlCl_3$ sludge is entrained in a second portion of n-butane fluid and passed into a high point of the reaction zone. The sludge is separated from its entraining fluid and flowed downwards through the bed in countercurrent contact with the first portion of n-butane. The second portion of n-butane and conversion products of the first portion are withdrawn from a high point in the reaction zone.

U.S.P. 2,393,857. Hydrocarbon Conversion. F. E. Frey to Phillips Petroleum Company.

An iso-paraffinic motor fuel is produced from normal butane. N-butane is isomerized by agitating it with an equal volume of concentrated HF containing about 0.1-3 mol percent of BF_3 at about 120°F. and under 140 psi pressure. The effluent is separated into a liquid hydrocarbon and a liquid catalyst phase. Isobutane is separated from the hydrocarbons and reacted with olefins in the presence of the catalyst phase. The alkylated products are removed from the catalyst and the latter is fractionally distilled to a low-boiling fraction comprising HF and BF_3 which is passed to the isomerization zone and a high-boiling fraction which is heated to 350-600°F. and decomposed to form HF and BF_3.

U.S.P. 2,394,412. Catalytic Conversion of Hydrocarbons. P. L. Veltman to The Texas Company.

An isomerization process is described, employing a liquid aluminum halide-hydrocarbon complex catalyst in the presence of a hydrogen halide promoter. Used complex contaminated with inactive material is withdrawn from the reactor to a scrubbing tower and is scrubbed at 70-150°F. with a liquid saturated hydrocarbon. A stream of hydrocarbons containing promoter is removed from the scrubbing tower and stripped and promoter material is recycled to the reactor.

U.S.P. 2,394,694. Isomerization of Saturated Hydrocarbons. E. R. Kanhofer to Universal Oil Products Company.

N-butane is contacted with an isomerization catalyst, such as $AlCl_3$ under con-

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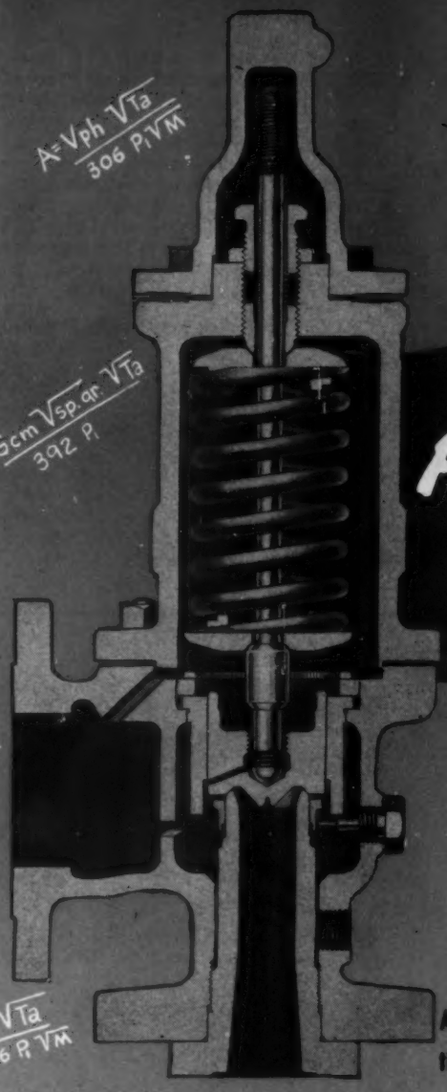

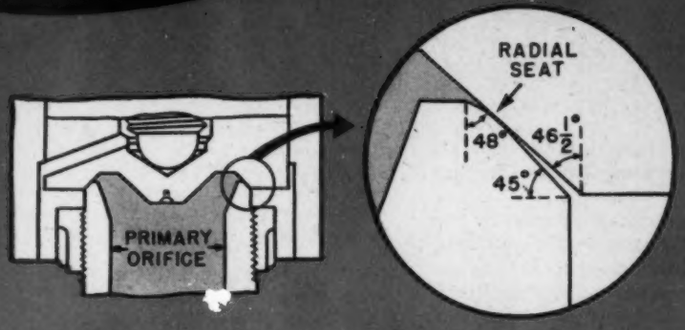

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ditions suitable to form a n-butane-catalyst mixture containing an amount of catalyst adequate to promote subsequent isomerization. The mixture and HCl are commingled in a packed reaction zone under conditions suitable to maintain vapor-phase isomerization of n-butane to isobutane. The flow of reactions is periodically interrupted and higher-boiling hydrocarbons are introduced into the zone, a substantial portion of which is isomerized by the action of catalyst deposited on the packing material. A hexane fraction may thus be isomerized in the presence of 10 mole percent of HCl at 212°F. and under 500 psi pressure.

U.S.P. 2,394,752. Isomerizing Hydrocarbons. C. C. Crawford and W. E. Ross to Shell Development Company.

A liquid-phase isomerizatoin process for paraffinic hydrocarbons is described which utilizes a fluid melt of $AlCl_3$, NaCl, and $ZnCl_2$ as a catalyst. A molar ratio of about 3:1:1 and a temperature of below 100°C. is employed.

U.S.P. 2,394,797. Process for the Production of a Blending Fuel. S. H. McAllister and N. E. Peery to Shell Development Company.

A normal hexane fraction is isomerized in the liquid phase in the presence of a Friedel-Crafts type of catalyst to methylpentane, which is admixed with cyclopentane and subjected to a liquid-phase isomerization process under relatively severe conditions. A fraction containing largely neohexane is recovered.

U.S.P. 2,394,803. Isomerization of Hydrocarbons. N. E. Peery to Shell Development Company.

Paraffinic hydrocarbons are isomerized by passage through a series of zones containing a supported Friedel-Crafts type isomerization catalyst of varying activity, the hydrocarbons passing through the least active catalyst first. A gradient of hydrogen decreasing in the direction of flow is maintained.

U.S.P. 2,394,810. Production of Branched-Chain Hydrocarbons. W. E. Ross to Shell Development Company.

Normal butane is isomerized at 90°C. and in the presence of HCl with a fluid catalyst containing antimony trichloride and 11 percent aluminum chloride. Spent catalyst residue to which fresh $AlCl_3$ is added is used to alkylate isobutane and ethylene to 2, 3-dimethyl butane at 25°C.

U.S.P. 2,394,898. Isomerizing Hydrocarbons. H. A. Cheney and F. M. McMillan to Shell Development Company.

Normal-paraffinic hydrocarbons are isomerized in the presence of a fluid melt consisting of a quaternary mixture comprising $AlCl_3$, NaCl, KCl and $ZnCl_2$ in a weight ratio of 75:7.5:7.5:10. Reaction temperatures not in excess of 150°C., when isomerizing n-butane and not in excess of 80°C. when isomerizing pentane are employed.

U.S.P. 2,394,906. Production of Motor Fuel. F. E. Frey to Phillips Petroleum Company.

A normal paraffin is mixed with used HF from an alkylation step and isomerized at 250-1000°F. under superatmospheric pressure. Isoparaffin is then alkylated with olefin in the presence of a HF catalyst.

U.S.P. 2,395,263. Isomerization Process. A. L. Foster to Phillips Petroleum Company.

Volatile metal halide catalyst is deposited on a porous granular supporting material such as pelleted granular bauxite by arranging the supporting material in a plurality of stationary beds and flowing vaporized catalyst through each bed individually so as to uniformly deposit the catalyst on the carrier.

U.S.P. 2,395,274. Isomerization Process. J. C. Hillyer and H. E. Drenan to Phillips Petroleum Company.

C_4 to C_8 olefins are isomerized by contact with a bauxite catalyst at 500-1200°F. and under 0-100 psi pressure. Cracking, dehydrogenation and polymerization are largely avoided under these conditions. The catalyst may or may not be impregnated with barium or strontium hydroxide. In the conversion of butene-1 to isobutylene an efficiency of 91 percent can be obtained.

ALKYLATION

U.S.P. 2,393,818. Alkylation of Aromatic Compounds. L. Schmerling to Universal Oil Products Company.

Alkylated aromatic hydrocarbons are formed by reacting an aromatic hydrocarbon with an olefin in the presence of a solution formed by adding an aluminum halide and a catalytically inert salt to a nitroparaffin. The inert salt is taken from the group of alkali and alkaline earth metal halides.

U.S.P. 2,394,368. Alkylation of Hydrocarbons. L. A. Clarke to The Texas Company.

The alkylation of isobutane with ethylene is carried out at 110-130°F. in the presence of an $AlCl_3$ catalyst in such a way that the catalyst is continuously washed with liquid hydrocarbons, removing undesirable $AlCl_3$-hydrocarbon complex compounds which otherwise coat the catalyst surface. Gaseous olefins are introduced into the bottom of the reaction tower while isoparaffins are introduced into the top, gaseous material is withdrawn from the top, liquid containing washed off catalyst complex and alkylated products from the bottom.

U.S.P. 2,394,696. Alkylation. R. A. Kinnear, H. B. Chamberlain, J. F. McCanne and J. C. Gordon to Socony-Vacuum Oil Company.

An isoparaffin and an olefin are reacted in the presence of a fluid acid catalyst. The invention contemplates a plurality of mixing devices. Means are provided for supplying both recycled reaction mass admixed with fresh catalyst and fresh feed stock admixed with recycled hydrocarbons to the mixing stream on portions in advance of each mixer.

U.S.P. 2,394,929. Catalytic Alkylation Process. M. P. Matuszak to Phillips Petroleum Company.

An improved process for the continuous alkylation of hydrocarbons in the presence of concentrated hydrofluoric acid as alkylation catalyst which comprises intimately admixing in liquid phase in a pretreatment step a low-boiling isoparaffin and only hydrofluoric acid separated from effluents of a subsequent alkylation step for a period of time sufficient to effect reaction between impurities in said hydrofluoric

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acid and said low-boiling isoparaffin, passing at least a portion of the effluents of said pretreatment to a first separator and separating a hydrofluoric acid phase and a hydrocarbon phase, passing said hydrocarbon phase to an alkylation step and reacting same under alkylation conditions with an added alkylating reactant to form high-boiling isoparaffins, in the presence of concentrated hydrofluoric acid as alkylation catalyst, passing effluents of said alkylation to a second separator and separating a hydrocarbon phase and a hydrofluoric acid phase, recovering from said hydrocarbon phase a hydrocarbon fraction containing high-boiling isoparaffins so produced as a product of the process, passing all of the last said hydrofluoric phase to said pretreatment step, passing at least a portion of the first said hydrofluoric acid phase from said first separator to a fractional distillation step, recovering as a low-boiling fraction substantially anhydrous hydrofluoric acid together with low-boiling paraffins dissolved in the hydrofluoric acid charged to said distillation step and passing same to said alkylation step.

U.S.P. 2,395,198. Alkylation and Olefin Recovery Process. W. A. Schulze to Phillips Petroleum Company.

A concentrated aliphatic olefin of at least 3 C atoms per mole is recovered from a feed stock containing the olefin in low concentration by passing a mixture of feed stock and benzene at 300°F. and under 400 psi over a granular synthetic silica gel activated with a minor proportion of alumina. Alkylbenzenes formed are cracked at 600-1000°F. and under 0-100 psi pressure in the presence of a synthetic silica-alumina catalyst and concentrated olefin is recovered from the cracked products.

U.S.P. 2,394,905. Alkylation of Benzene. F. E. Frey to Phillips Petroleum Company.

Normally gaseous alkyl fluorides from an alkylation process are recovered by absorption in liquid substantially anhydrous HF. Used HF is agitated with small proportions of polyethylbenzenes whereby the used acid is revivified and the yield of ethylbenzene is increased.

POLYMERIZATION, CONVERSION

U.S.P. 2,394,407. Polymerization of Heat Polymerizable Aromatic Olefin. F. J. Soday to United Gas Improvement Company.

The crazing of polystyrene is retarded or completely eliminated and its initial softening point increased by polymerizing monomeric styrene at a temperature below 200°C. by means of infrared radiation with a majority of the rays lying between 10,000 and 20,000 Å.

U.S.P. 2,394,641. Catalytic Polymerization of Unsaturated Hydrocarbons. F. J. Soday to United Gas Improvement Company.

To polymerize cyclopentadiene, a large proportion of a hydrocarbon solvent preferably of aromatic nature, and a small proportion of a surface active clay such as Attapulgus Clay, Tonsil, kaolin, etc., is mixed and cyclopentadiene is slowly added to the mixture while keeping it at a temperature not in excess of 120°C. The proportion of

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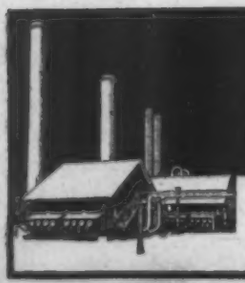

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catalyst to cyclopentadiene is 10-50 percent by weight and the reaction is stopped while soluble polycyclopentadiene is present in the reaction mass.

U.S.P. 2,394,716. Production of Aviation Gasoline. D. Read, Jr., to Universal Oil Products Company.

A gasoline fraction low in olefins is prepared from one high in olefins and containing C_5 olefins by fractionating the charge stock to separate a liquid product substantially free of C_5 and lower-boiling hydrocarbons and a fraction consisting of C_5 and lower-boiling hydrocarbons. The liquid product is catalytically cracked to effect a substantial reduction in its olefin content and the C_5 fraction is alkylated with isobutane. A portion of the alkylate is blended with gasoline-boiling-range hydrocarbons from the cracking step.

U.S.P. 2,394,743. Blending Fuels. J. Bergsteinson to Shell Development Company.

A high anti-knock blending fuel is produced by forming an isobutylene polymer boiling between 170 and 250°C., hydrogenating the polymer and cracking the product in contact with a chromium oxide catalyst at 425-550°C. and under 1-10 atm. pressure to lower-weight hydrocarbons.

U.S.P. 2,395,327. Process for Polymerizing Olefinic Materials. W. E. Hanford to E. I. duPont de Nemours & Company.

Ethylene is polymerized in an aqueous medium in the presence of benzyl peroxide as a catalyst. The pH is adjusted in the range of 1-6 and a reaction temperature of 20-350°C. and a pressure of 50-3000 atm. is employed. The more acid the medium, the shorter is the induction period and the more rapid the rate of reaction.

HYDROGENATION, DEHYDROGENATION, AROMATIZATION

U.S.P. 2,393,909. Chemical Reactions with Fluidized Solids. E. A. Johnson to Standard Oil Company (Indiana).

The method of controlling the temperature of an exothermic reaction of hydrogen and carbon monoxide and of dissipating the heat of reaction is described which comprises the steps of maintaining a mass of finely divided iron catalyst within a reaction zone, introducing CO and hydrogen at a low point in the reaction zone, withdrawing gaseous reaction products from the top of the zone, passing reacting gases upwardly through the mass to maintain the catalyst in a dense, turbulant suspended phase, intimately contacting with said catalyst a solid heat-absorbing material having a greater settling rate from that of suspended catalyst, said material being inert under the conditions within the reaction zone, conducting said exothermic reaction in the presence of said catalyst and said solid heat-absorbing material, absorbing heat from said exothermic reaction as sensible heat of the added solids, thereby maintaining the temperature at about 590-610°F., separating the heated solids from the catalyst by the classifying action of the upwardly flowing stream of gasi-

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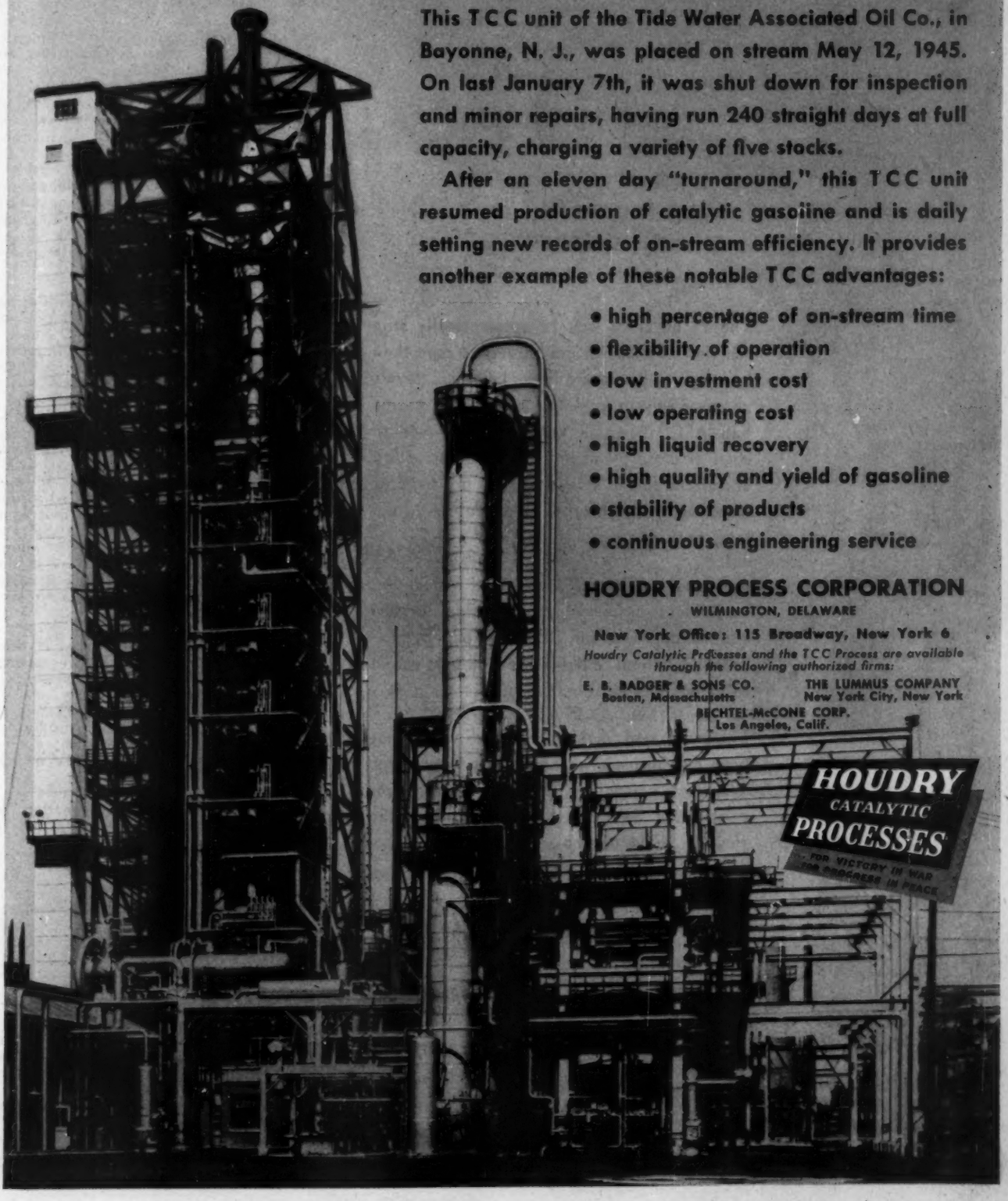

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form fluids within the reaction zone, withdrawing the separated solids from a low point in said zone, cooling said heat-absorbing material outside the exothermic reaction zone to a temperature substantially below the desired reaction temperature, and introducing the relatively cool solids into the exothermic reaction zone at a high point therein.

U.S.P. 2,394,170. Treatment of Hydrocarbons. A. V. Grosse and W. J. Mattox to Universal Oil Products Company.

Aliphatic hydrocarbons containing 6-12 carbon atoms per mol are subjected at a temperature of 850-1200°F. and under a pressure of atmospheric to 100 psi for a time of from 0.1 to 60 seconds to contact with a catalyst comprising 98-75 percent of activated alumina and 2-25 percent of chromium sesquioxide. The product consisting of paraffins, olefins and aromatic hydrocarbons is extracted with liquid sulfur dioxide to remove paraffinic hydrocarbons which are recycled. The olefins and aromatics are contacted with a catalyst of the same composition in a different zone for a period of 1-100 seconds to produce a substantially olefin-free aromatic product.

U.S.P. 2,394,625. Process for Producing Diolefins. M. P. Matuszak to Phillips Petroleum Company.

The dehydrogenation of paraffinic hydrocarbons to diolefins is carried out in two steps. In the first, paraffins are dehydrogenated to olefins in the presence of a highly active chromium oxide catalyst at 850-950°F. The effluent is then contacted in a second step with less active chromium oxide at 1100-1200°F. Diolefins are separated and paraffins and olefins are recycled in admixture with effluent from the first zone to the second zone. A gel catalyst containing equimolecular amounts of alumina and chromium oxide is used in the first, an impregnated alumina catalyst containing 15 percent chromia in second zone.

U.S.P. 2,394,691. Destructive Hydrogenation of Polycyclic Hydrocarbons. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

1, 1, 2, 3-tetra-methylcyclohexane is prepared from pinane and pinene by destructive hydrogenation in the presence of hydrogen and a catalyst (nickel-kieselguhr) at 125-350°C.

U.S.P. 2,394,739. Dehydrogenation of Hydrocarbons. R. C. Archibald to Shell Development Company.

Dehydrogenation catalysts consisting of metal sulfides such as tungsten and/or nickel sulfide are reactivated by passing a slow stream of sulfur dioxide over them at about 500°C. and under atmospheric pressure conditions. The catalyst is then flushed with hydrogen. After several such reactivations, accumulated carbon deposits are burned off the catalyst and the catalyst is resulfidized.

U.S.P. 2,394,849. Process for Treating Hydrocarbons. T. F. Doumani and C. H. O. Berg to Union Oil Company.

Butadiene is obtained from a gasoline feed stock by burning hydrocarbon fuel to obtain spent fuel gas having a temperature above about 2000°F., mixing the hot spent fuel gas with the hydrocarbons to be treated and fluid

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catalysts of the magnesia or vanadium trioxide type and passing the mixture to a reaction zone. The temperature of the mixture is suddenly lowered to a point where no further reaction takes place and the desired fraction is separated from the product.

U.S.P. 2,395,016. Process for the Dehydrogenation of Hydrocarbon. W. A. Schulze and J. C. Hillyer to Phillips Petroleum Company.

Normal-butane is catalytically dehydrogenated to butene-1 and butene-2 with simultaneous formation of butadiene and isobutene. The butenes are isomerized with conversion of butene-1 to butene-2 as the principal reaction. Butadiene and butene-2 are separated from the effluent of the isomerization zone and the butene-2 is dehydrogenated to butadiene in a second step with formation of some butene-1 occurring as a side reaction.

DESULFURIZATION

U.S.P. 2,394,678. Process for Obtaining Low Sulphur Diisobutylene Polymer. M. Frankel and M. S. Agruss to The Pure Oil Company.

A C_4 fraction obtained by stabilizing cracked gasoline distillate with sulfuric acid of 65 percent concentration at 20-45°C. and under sufficient pressure to maintain liquid phase is separated into two fractions one of which contains diisobutylene. By contacting the polymers with boiling caustic soda and then with siliceous absorptive material such as silica gel, fullers' earth or other similar neutral or synthetic clays, sulfur compounds in the polymer can be completely eliminated.

U.S.P. 2,394,751. Desulphurization of Aromatic Hydrocarbons. R. M. Cole to Shell Development Company.

Aromatic hydrocarbons are desulfurized by hydrogenation in the presence of a metal sulfide catalyst at 450-825°F. and a pressure above 10 atmospheres. Hydrogenation of the aromatics is prevented by addition of 1-5 percent of olefins of a type which may be separated from the product by distillation.

HEAVY OILS AND WAXES

U.S.P. 2,394,536. Compounded Lubricating Oil. G. H. Denison, Jr., and P. C. Condit to California Research Corporation.

A composition of a hydrocarbon oil containing a minor proportion of an antioxidant of the formula

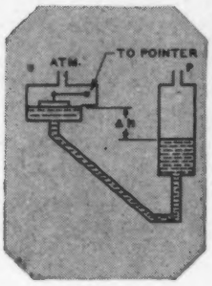
$$R_1 — (S)_n — R_2$$

wherein R_1 and R_2 are aliphatic groups and n is a whole number from 1 to 3 is described. The composition further contains not less than 0.05 percent of a salt of a thiocarbamic acid containing an organic substituent.

U.S.P. 2,394,567. Lubricating Grease Composition. L. W. Sproule and J. C. Zimmer to Standard Oil Development Company.

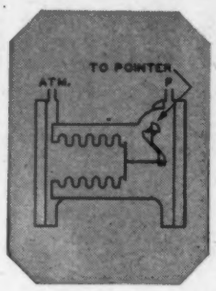
Aluminum soap greases are prepared by mixing at 280-300°F. a viscous mineral oil with 3-10 percent aluminum

do under Pressure...



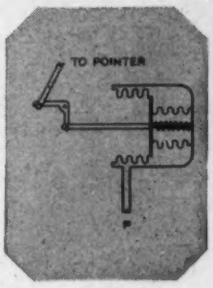
U-tube manometer

Mercury U-tube with float on surface. Cast iron or steel. Range limits: 0-10 to 0-200" water.



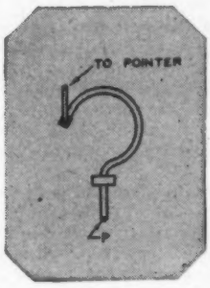
aneroid manometer

Steel body with bellows of bronze or 18-8 alloy. Torque tube, no stuffing box. Ranges: 0-20 to 0-500" water; 0-20 to 0-100 psi.



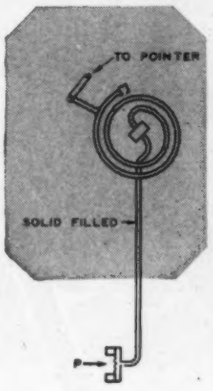
bellows

Sealed bellows, no stuffing box. Bellows and housing bronze. Ranges: 0-3 to 0-25 psi.



C spring*

Variation of multi-coiled bourdon spring. Entirely steel. Ranges: 0-2001 to 0-10,000 psi.

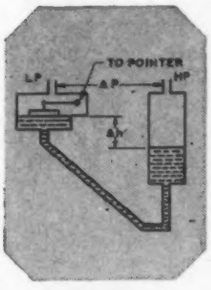


diaphragm*

Self-contained. For measuring sludges, etc. Diaphragm of any material. Maximum length of tubing 50 ft. Ranges: 0-15 to 0-500 psi.

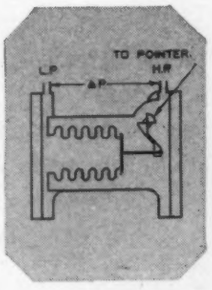
volumetric pressure for liquids*

Steel (silver plated for sanitary services). Compression of bulb actuates spring. Temperature compensation permits tubing up to 35 ft. Range: 0-5000 psi.



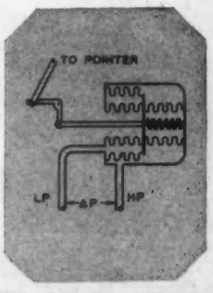
U-tube manometer

Mercury U-tube with float on surface. Cast iron or steel. Ranges: 0-10 to 0-200" water.



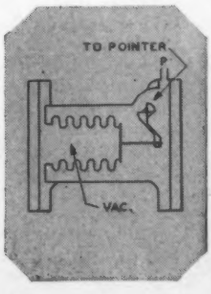
aneroid manometer

Steel body with bellows of bronze or 18-8 alloy. Torque tube, no stuffing box. Ranges: 0-20 to 0-200" water (0-500" on order).



bellows

Sealed bellows, no stuffing box. Bellows and housing bronze. Ranges: 0-5 to 0-25 psi.



aneroid manometer

Steel body with bellows of bronze; torque tube of stainless steel; no stuffing box. Ranges: 0 to 20 to 0-500" water absolute, or equivalent units of measurement.

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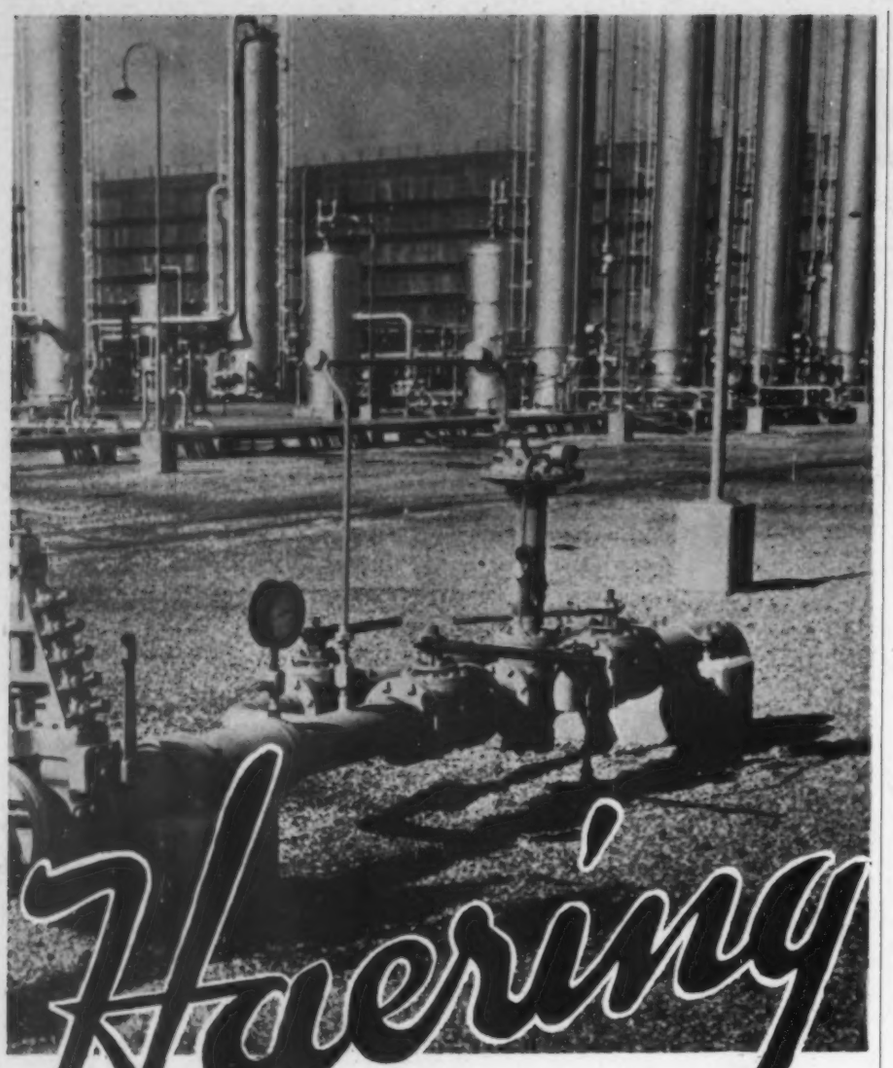

stearate and 0.25-1.5 percent of an alkyl phenol such as tert. octylphenol.

U.S.P. 2,395,093. Mineral Oil Composition. J. H. Bishop to Socony-Vacuum Oil Company.

In order to impart anti-rusting and demulsifying properties to mineral lub oils containing an oxidation or corrosion inhibitor, small amounts of an oil-soluble alcohol extract of blown lard oil are incorporated into the lub oil.

California Association Issues Revised LPG Standards

California Natural Gasoline Association, 510 West Sixth Street, Los Angeles 14, has released its Bulletin Ts-441, "Tentative Specifications and Tentative Standard Methods of Test for Liquefied Petroleum Gas," price $1.50 per copy. It replaces the former bulletin Ts-392, published in 1939.

The new bulletin embodies new material and improvements in testing and gauging procedures developed meanwhile. It contains a new set of tables of volume correction factors for converting observed volumes to volumes at 60° F. This table is based on latest available information concerning the variations of volumes with temperature of LPG products. One new section on the computation of vapor pressures has been added, including a chart of corrected vapor pressure of LPG mixtures to greater accuracy than previously possible. There is a formula for blending LPG stocks to produce mixture of specified vapor pressure.

Among the new test methods is one for determining vapor pressures and specific gravities. There is a simple and rapid method for determining propane, isobutane n-butane and isopentane. A new method for determining water content of LPG is presented.

The bulletin contains specifications for six standard CGNA grades of LPG. There also is a table of physical constants of the light hydrocarbons and a vapor-pressure correction chart for LPG products.

Rumford Chemical Works Increases Research Staff

Two additions to the research laboratory staff of Rumford Chemical Works, Rumford, Rhode Island, have been announced.

John R. Van Wazer, Ph.D., formerly in charge of a physical chemistry laboratory in the Tennessee Eastman Corporation division of the Clinton Engineering Works at Oak Ridge, will serve as a physical chemist. A Phi Beta Kappa graduate of Northwestern University in 1940 with a bachelor of science degree, Van Wazer received his master's and doctorate degrees in 1941 and 1942 respectively at Harvard University, where he was a University Fellow. He was a research chemist in the department of manufacturing experiments for Eastman Kodak Company, Rochester, New York, from 1942 to 1944.

Robert H. Elliott, M. D., an inorganic chemist for seven years at the Laurel Hill Research Laboratory of General Chemical Company, Long Island, will hold a similar position with Rumford Chemical Works. A graduate of the University of New Hampshire in 1936 with a bachelor of science degree, Elliott received his master's degree the following year at the University of Vermont, where he held the Eli Lilly Fellowship.

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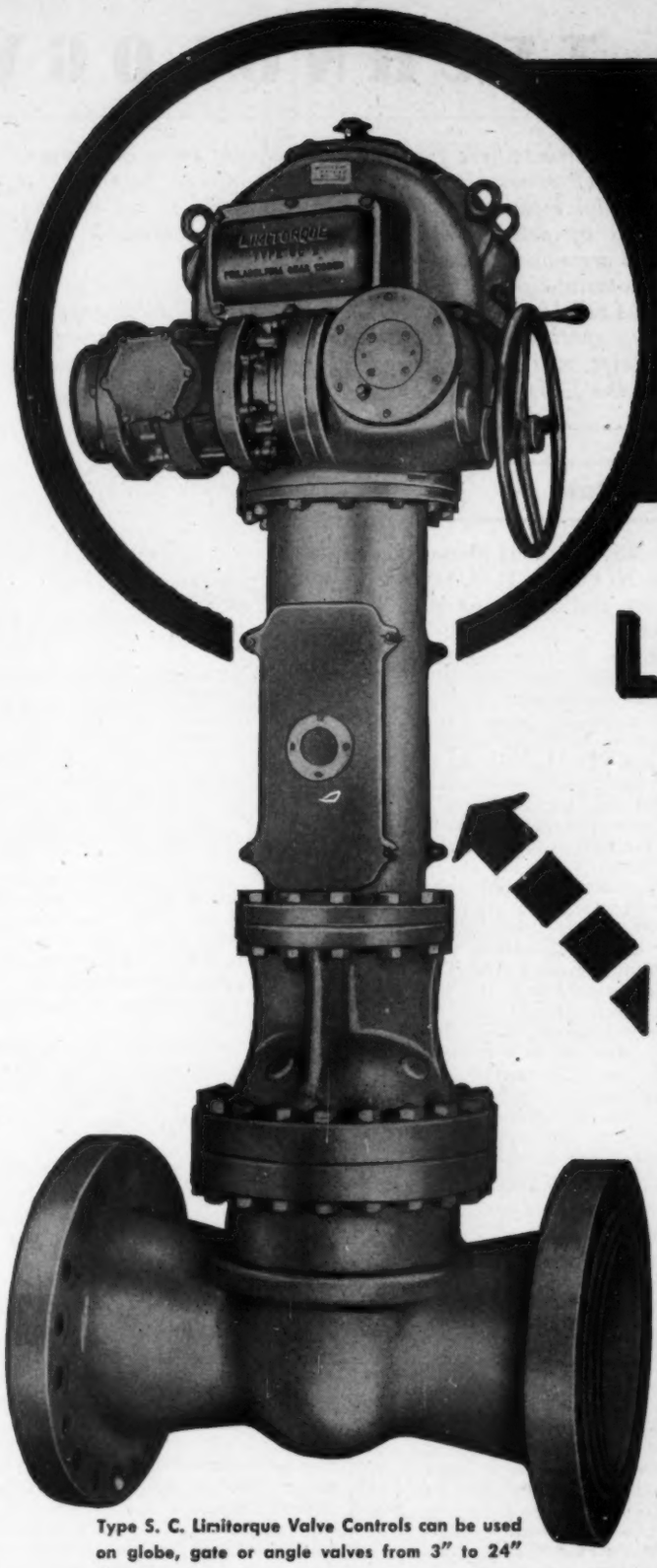

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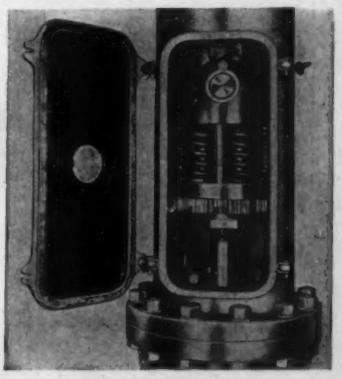

View showing spring compensated cross head guiding valve stem and connection with valve stem. Thrust adjustment mechanism and thrust indicator.

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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

The Heat Capacities, Heats of Transition, Heats of Fusion and Entropies of Cyclopentane, Methylcyclopentane and Methylcyclohexane. D. R. DOUSLIN AND H. M. HUFFMAN. *Jour. Amer. Chem. Soc.* **68** (1946) pp. 173-76.

The Bureau of Mines has recently begun a research program to obtain precise and accurate values of the thermodynamic constants of hydrocarbons and related compounds. The paper presents the results of the low-temperature study of three naphthenes, cyclopentane, methylcyclopentane, and methylcyclohexane. Heat capacity data are given on these hydrocarbons over the range 12° to 300° K. Melting points, temperatures of transition, heats of fusion and heats of transition were determined and are given. The entropy values for the substances in liquid state at 298.16° K. were calculated.

Chemicals Wanted

The National Registry of Rare Chemicals, Armour Research Foundation, 33rd, Federal, and Dearborn streets, Chicago 16, Illinois, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only one gram quantities, please inform the Registry.

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- Pyrrolidine
- 2-Hydroxy-6-isopropyl benzoic acid
- Sodium or potassium dithio oleate
- Potassium dithio stearate
- 1,1-Diphenyl ethane
- 1,1-Dibrom propane
- 2-Phenyl cyclohexanol
- 1,2-Dodecylene chlorohydrin
- Humic acid
- Pentamethylene diamine
- Tetramethylene diamine
- Amino actone
- 3-Amino-2-butanone
- Trimethylene diamine
- 3,4-Dihydroxypyridine
- 3,4-Dihydroxypyridine-6-carboxylic acid
- Diphenyl phosphate
- Thiazole-5-carboxylic acid
- Cyclobutane

Boiling Point Relations Among Mononuclear Aromatics. N. CORBIN, M. ALEXANDER AND G. EGLOFF. *Ind. & Eng. Chem.* **38** (1946) pp. 156-59.

The boiling points of mononuclear aromatic hydrocarbons were recently collated and critically evaluated by one of the authors. The present paper deals with the relationship between boiling point and structure. The variation of boiling point with the number of carbon atoms was determined for ten homologous series of mononuclear aromatic hydrocarbons. The equation for the relationship is in the form: $t = a \log (n_c + 4.4) + k$. The variation of the difference in boiling point between an aliphatic compound and its phenyl derivatives with the number of carbon atoms was studied for nine homologous series. The equation is of the form: $\delta = p + q \log n_c$. Comparisons were made among phenylalkanes, phenylalkenes, and phenylalkynes; phenylalkanes and phenylcyclanes; 1-phenyl and 2-phenyl compounds, and monophenyl and polyphenyl compounds. The data are presented in graphical form in three figures.

Rapid Estimation of Effect of Pressure upon Boiling Points of Organic Compounds. C. BORDENCA. *Ind. & Eng. Chem., Anal. Ed.* **18** (1946) pp. 99-101.

It is convenient to have at hand a means for rapidly estimating the boiling point of a substance at pressures other than those under observation. Various methods have been proposed for this purpose, one of the most useful being that of Cragoe as modified by Hass and Newton. However the computations involved in this method are time-consuming. The object of the present work was to reformulate the Hass-Newton equation, and to derive graphs suitable for rapid interconversion which will be useful especially in connection with ordinary laboratory distillation. Graphs are presented for eight classes of compounds from which boiling points at various pressures can be read by interpolation.

Freezing Points and Polymorphism of the Eight C_9H_{12} Alkylbenzenes. A. E. HIRSCHLER AND W. B. M. FAULCONER. *Jour. Amer. Chem. Soc.* 68 (1946) pp. 210-14.

All eight of the isomeric C_9H_{12} alkylbenzenes were prepared in the laboratory and freezing points, purities, densities and refractive indices were determined for each substance. Two freezing points were observed for four of the hydrocarbons, namely, pseudocumene, 1,2- and 1,3-methylethylbenzenes, and n-propylbenzene. Mesitylene was found to show three freezing points, two of which had been previously reported. The densities and refractive indices of the alkylbenzenes are as follows:

Hydrocarbon	Density 20/4	Refractive index $n^{20}D$
n-Propylbenzene	0.8621	1.4921
Isopropylbenzene	.8620	1.4914
1-Methyl-2-ethylbenzene	.8808	1.5043
1-Methyl-3-ethylbenzene	.8648	1.4965
1-Methyl-4-ethylbenzene	.8618	1.4950
1,2,3-Trimethylbenzene	.8944	1.5138
1,2,4-Trimethylbenzene	.8761	1.5047
1,3,5-Trimethylbenzene	.8653	1.4991

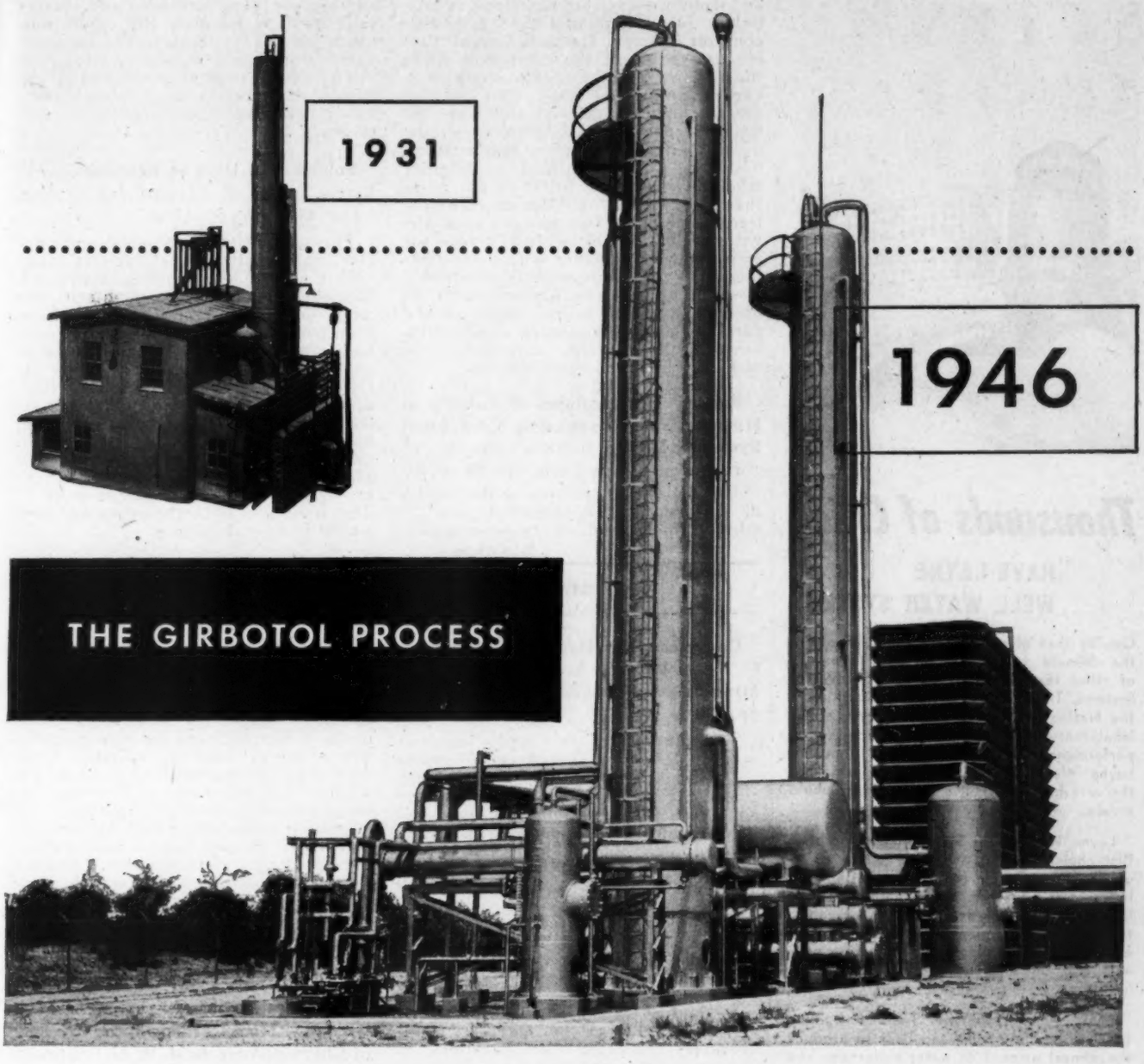
Transition temperatures of hemimellitene were redetermined, together with approximate values of the heats of transition. These data were used to calculate approximate values for the metastable freezing points of hemimellitene II and III, which have not yet been observed experimentally. A procedure is described that aids in the determination of what portion, if any, of a given time-temperature freezing or melting curve is suitable for the calculation of the purity of the compound.

The Representation of the Vapour-Liquid Equilibrium Relation by Means of a New Graphical Method. A. L. BLOOMFIELD. *Trans. Inst. Chem. Engrs.* **20** (1942) pp. 78-96.

A form of diagram is described that is capable, by means of straight lines only, of correlating the compositions of vapors and liquid for binary mixtures of invariant separability, and by means of straight lines and a circle of correlating such compositions for homogeneous binary mixtures of all known types. The method is illustrated by examples, and is shown to be of considerable accuracy. The form of the relationship is given both graphically and analytically. It has been shown that the entire equilibrium relations for a given homogeneous mixture can be summed up in four numerical values (the principle correlatives) and that if these are known the whole relation can be explored on a standard diagram with no equipment other than pins and threads. A convenient device for more rapidly working with threads has been described. The characteristic points for a given mixture can be obtained from experimental data by a graphical construction.

Determination of the Purity of Hydrocarbons by Measurement of Freezing Points. A. R. GLASGOW, JR., A. J. STREIFF AND F. D. ROSSINI. *J. Res. Natl. Bur. Standards* **35** (1945) pp. 355-73.

The apparatus and procedure used for determining the freezing point of hydrocarbons from time-temperature freezing



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and melting curves are described. A procedure for determining the cryoscopic constant is given. Methods for calculating the purity of the compound when the freezing point for zero impurity is known, and when it is unknown, are given. Duplicate determinations of the freezing point by a given operator usually differ by not more than 0.002 to 0.005° C., while those made in different laboratories should differ by not more than 0.01 to 0.02° C. Measurements of freezing points of best samples available, with evaluation of freezing points for zero impurity, together with determinations of cryoscopic constants as required, have been made on approximately 80 different purified hydrocarbons of the paraffin, alkylcyclopentane, alkylcyclohexane, alkylbenzene, monoolefin, diolefin and cyclomonoolefin series.

Further Investigations of Polarity in Hydrocarbons Possessing Conjugated Systems. N. B. HANNAY AND C. P. SMYTH. *Jour. Amer. Chem. Soc.* **68** (1946)

The dielectric constants of the vapors of 1,2-dimethyl, 1,3-dimethyl, and 2-ethylbutadiene and of cyclopentadiene and styrene were measured and the results used to calculate the dipole moments of the molecules. The moment values were found to be consistent with the molecular structures required by the theory of hyperconjugation and resonance, and thus lends support to this theory.

Solubility of DDT in Kerosines. E. E. FLECK AND H. L. HALLER. *Ind. & Eng. Chem.* **38** (1946) pp. 177-8.

The solubilities of technical and pure DDT in several kerosines over the range 130° C. to +30° C. were determined. Kerosine obtained from naphtenic-base crude oils dissolve more DDT than those from paraffinic-base crude oils. The aniline point of the kerosine can be used as a general guide to its solvent power for DDT. The addition of petroleum fractions rich in alkylated naphthalenes retards the crystallization of DDT from kerosine solution held at —30° C. In general the solubilities range from 1 to 3 grams of DDT per 100 grams of solvent at —30° C., to 8 to 20 grams at +30° C. The solubility and other data are presented in five tabulations.

Chemical Compositions and Reactions

Conversion of n-Heptane to Isobutane. O. GRUMMITT, E. N. CASE AND C. V. MITCHELL. *Ind. & Eng. Chem.* **38** (1946) pp. 141-44.

The purpose of the study reported was to determine the effect of certain added metals on the heptane-aluminum chloride reaction when effected under conditions that give relatively high isobutane yields. Experiments with water- or hydrogen chloride-promoted aluminum chloride and n-heptane, with and without the addition of sodium, magnesium, or aluminum, were run at 95-100°C. and atmospheric pressure to determine the yields of isobutane, light paraffins (C_5-C_7), heavy paraffins (C_8 and higher) and the oil from the catalyst complex. These metals exert a very marked influence on the promoted catalyst as shown by decreased conversions, increased isomerization to light paraffins, and decreased cracking-isomerization to isobutane and oil. Because aluminum has the greatest effect in retarding oil formation, which inactivates the catalyst, it is the best of the three metals tested for controlling this reaction as a means of producing isotubane and light paraffin hydrocarbons.

The Mechanism of the Alkylation of Paraffins. II. Alkylation of Isobutane with Propene, 1-Butene and 2-Butene. L. SCHMERLING. *Jour. Amer. Chem. Soc.* **68** (1946) pp. 275-81.

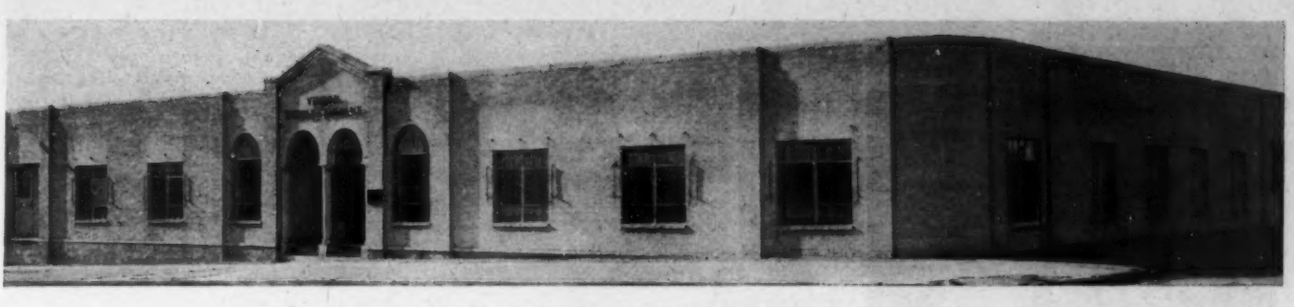
As part of the study of the mechanism of the alkylation of isoparaffins with olefins, the products obtained by the alkylation of isobutane with 1-butene and 2-butane were compared. According to the recently proposed theory of the alyklation mechanism, these butanes should yield different octanes as the major alkylation products. It was found that the alkylates obtained by the reaction of isobutane with 1-butene and 2-butene in the presence of aluminum chloride monomethanolate and hydrogen chloride differed markedly in that the former contained about 60 percent of dimethylhexanes and 10 percent of trimethylpentanes whereas the latter contained about 65 percent of trimethylpentanes and only 4 per cent of dimethylhexanes. A similar difference in the composition of the two products was observed when unmodified aluminum chloride was used as catalyst; the alkylation in this instance, however, was accompanied by more side reaction. The alkylation of isobutane with propene using aluminum chloride monomethanolate as catalyst yielded a liquid product more than half of which was heptane and consisted of approximately equal quantities of 2, 3- and 2, 4-dimethylpentane. The mechanism of the alkylation reactions is discussed and the difference in composition of the butene products is explained.

Condensation of Aliphatic Alcohols with Aryl Hydrocarbons in the Presence of Chlorosulfonic Acid. W. H. C. RUEGGEBERG, M. L. CUSHING AND W. A. COOK. *Jour. Amer. Chem. Soc.* **68** (1946) pp. 191-92.

The alkylation of benzene and some of its derivatives with secondary and tertiary monohydric aliphatic alcohols in the presence of chlorosulfonic acid is described. The preferred method consists of the slow addition of one mole of chlorosulfonic acid to a mixture of one mole of alcohol and three moles of the aromatic hydrocarbon at a temperature of about 10°C. Primary alcohols, with the exception of benzyl alcohol, did not enter into the condensation reaction.

Selective Demethylation of Paraffin Hydrocarbons. V. HAENSEL AND V. N. IPATIEFF. *Jour. Amer. Chem. Soc.* **68** (1946) pp. 345-46.

The authors make record of a new reaction, the selective demethylation of paraffin hydrocarbons by reaction with hydrogen. This results in the removal of specific methyl groups as methane and the formation of a paraffin having one less carbon atom. The methyl groups attached to secondary carbon



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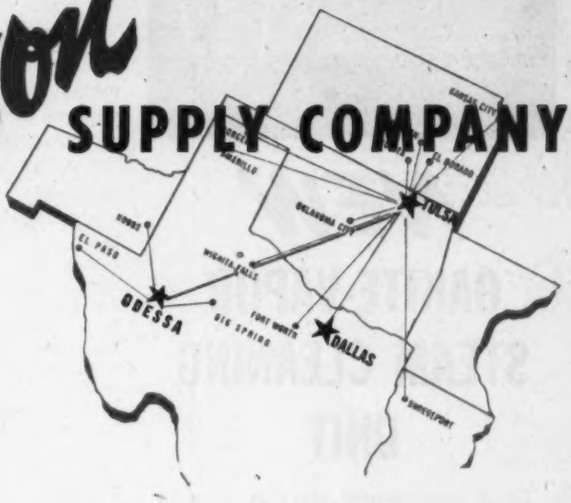

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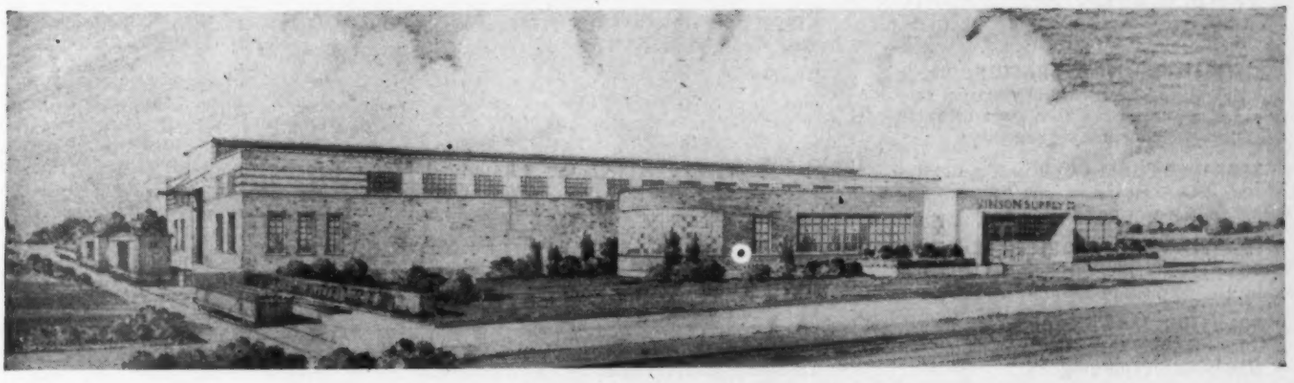

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atoms are removed much more readily than those attached to tertiary carbon atoms, while those bound to quaternary carbon atoms are the most stable. The reaction is effected using nickel or cobalt catalysts with preferred temperatures ranging from 200-300°C. and pressures from atmospheric to 50 atmospheres. Careful control of reaction conditions at properly related values of temperature and pressure within these general ranges is essential. When conditions are so controlled, there is no carbon deposition, and the catalyst activity is maintained for long periods. A typical example of the demethylation of neohexane is given.

The Depolymerization of 3,4,5,5-Tetramethyl-2-hexene and 3,5,5-Trimethyl-2-heptene in Relation to the Dimerization of Isoamylenes. F. C. WHITMORE AND W. A. MOSHER. *Jour. Amer. Chem. Soc.* **68** (1946) pp. 281-84.

The polymerization of the isoamylenes by the action of sulfuric acid yields the two decenes 3, 4, 5, 5-tetramethyl-2-hexene and 3, 5, 5-trimethyl-2-heptene. 3, 5, 5-Trimethyl-2-heptene was depolymerized with 1-chloro-4-napthalenesulfonic acid to yield trimethylethylene. 3, 4, 5, 5-Tetramethyl-2-hexene was depolymerized with 1-chloro-4-napthalenesulfonic acid to yield isobutylene, isoamylenes, 3-methyl-2-pentene, diisobutylenes and nonenes. The dimerization of isoamylene is discussed in detail in relation to the absence of the predicted 2, 3, 4, 4-tetramethylhexenes. Further evidence is presented and discussed for a 1, 3-shift of methyl in certain carbonium ions.

Preparation of Olefins from Aldehydes and Ketones. R. H. GRIFFITH. *J. Chem. Soc.* (1945) p. 715.

The reactions were effected over a catalyst prepared by heating molybdic acid in a stream of hydrogen at 400°C. for 2 hours. The liquid aldehyde or ketone to be treated was added to a stream of hydrogen so that about 10 moles of hydrogen accompanied each mole of organic compound. The mixture was passed through 20 grams of catalyst heated to 400°C. It was found best to leave 30-40 percent of unchanged aldehyde or ketone so as to prevent reduction of the double bond. The yield of olefin was found to be approximately 60 percent Pr_2 CO gives 3-heptene, heptaldehyde gives the 1-isomer, and PhAc gives PhCH: CH_2.

The Chemistry and Constitution of Asphalts. B. A. MURPHY. *Jour. Inst. Petr.* **31** (1945) pp. 475-85.

The term "asphalt" is used to include naturally occurring asphalts and all bitumens or asphaltic bitumens produced from crude petroleum. Typical analyses of asphalts are given, and the effect of blowing on asphaltic components is shown. Blown asphalts contain more asphaltene and fewer oily components than the corresponding steam refined grade, and the ration of asphaltenes to resins is higher for blown asphalts. The nature of the various components of asphalt is briefly considered, as well as the chemical composition of asphalt. The question of the spatial configuration of the molecular structure is discussed. A tentative structure for asphaltic molecules is presented. From the evidence presented in the paper the author concludes that a proposed structure for molecules of the asphaltic components must meet at least six different specifications. These specifications are given.

Pure Hydrocarbons from Petroleum. J. GRISWOLD AND C. F. VAN BERG. *Ind. & Eng. Chem.* **38** (1946) pp. 170-77.

A pilot plant for extractive distillation is described. The process was applied to the separation of the narrow-boiling heptane fractions (Skellysolve C) from Mid-Continent natural gas. Pure heptane was prepared by two operations. The pilot plant and its performance are described when operating at different reflux ratios in separating the heptane fraction into paraffinic, napthenic, and aromatic cuts. Pure heptane was obtained from the paraffinic portion by batch fractionation.

Manufacture: Processes and Plant

Dehydroisomerization of n-Butane. H. S. BLOCH AND R. E. SCHAAD. *Ind. & Eng. Chem.* **38** (1946) pp. 144-47.

The investigation reported was undertaken to determine whether the conversion of n-butane to isobutylene can be effected in a one-stage process rather than the usual two-stage procedure. The conversion of n-butane into a mixture of n-butylenes and isobutylene was effected at atmospheric pressure with a catalyst comprising a dehydrogenating component (chromia-alumina) and an olefin-isomerizing component (silica-alumina-thoria). A catalyst bed composed of a mixture of granules of the two components was much more effective than a bed of granules made of the mixed powders. Under the most favorable conditions (525-575°C., gaseous hourly space velocities of 500-1200), butylene yields of 25-30 percent were obtained with a dehydrogenating efficiency of approximately 85 percent. About one fourth of the yields of butylene was isobutylene.

Hydrogen Fluoride-Paraffin Systems. E. B. BUTLER, C. B. MILES AND C. S. KUHN, JR. *Ind. & Eng. Chem.* **38** (1946) pp. 147-55.

From a practical point of view, knowledge of the solubility relationships in hydrogen fluoride-paraffin hydrocarbon systems is important for the proper design and operation of those parts of the alkylation plant the function of which is the recovery and separation of hydrogen fluoride. Despite the rather small solubility of hydrogen fluoride in the streams, the value of the dissolved acid may amount to a large fraction of the value of the alkylate produced. Mutual solubilities of low-molecular-weight hydrocarbons (isobutane, n-butane, propane) and of hydrogen fluoride in two liquid-phase systems, with and without water and alkylate, were determined for the range of temperature 0-50°C., and with alkylate concentrations up to 30 percent by

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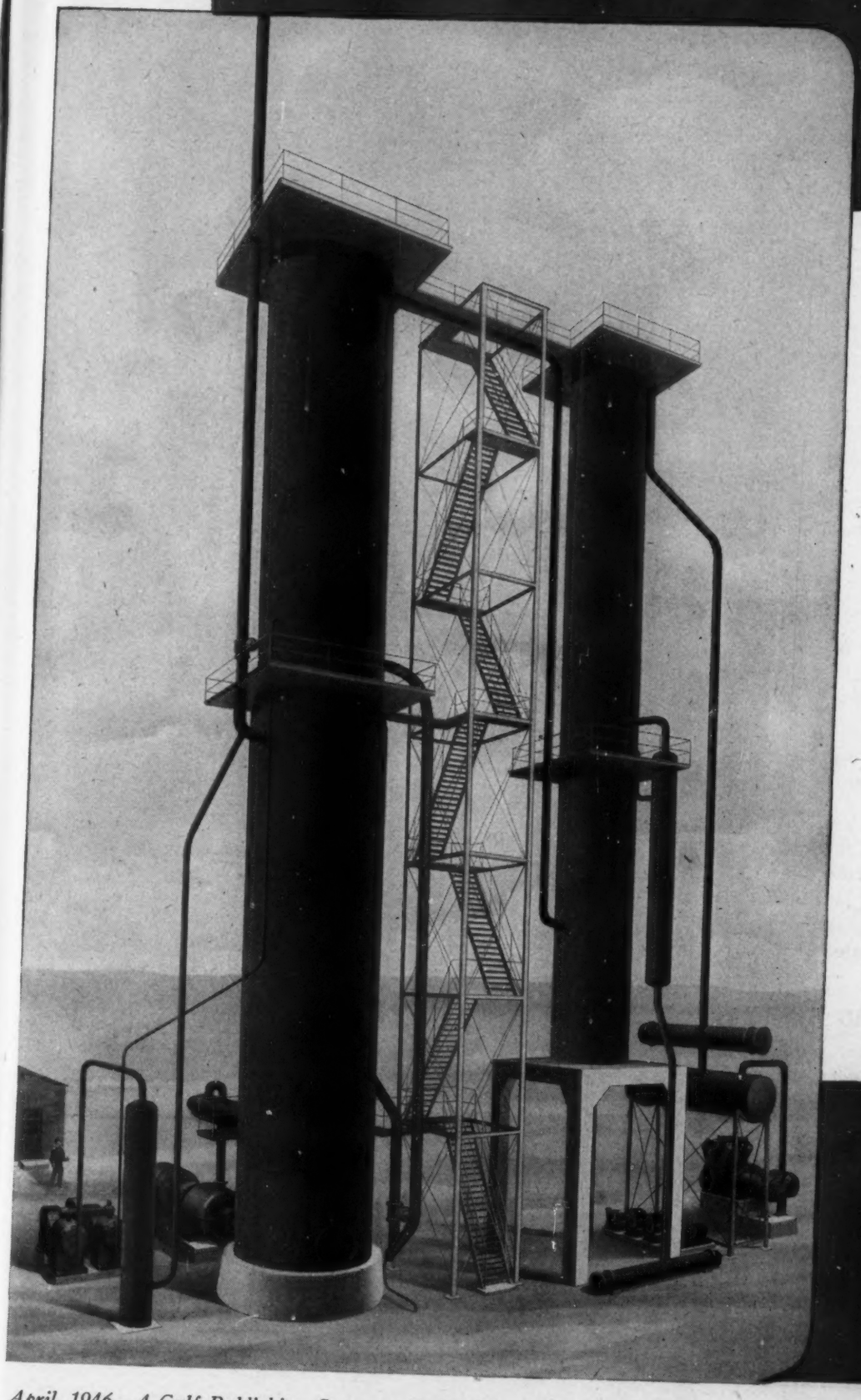

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weight in the hydrocarbon phase, and water contents up to about 10 percent by weight in the acid phase. Anomalous solubilities of isobutane in the presence of alkylate and water are considered to be related to the greater alkylating activities of isoparaffins. Tentative correlations of the data with analyses of plant streams are given.

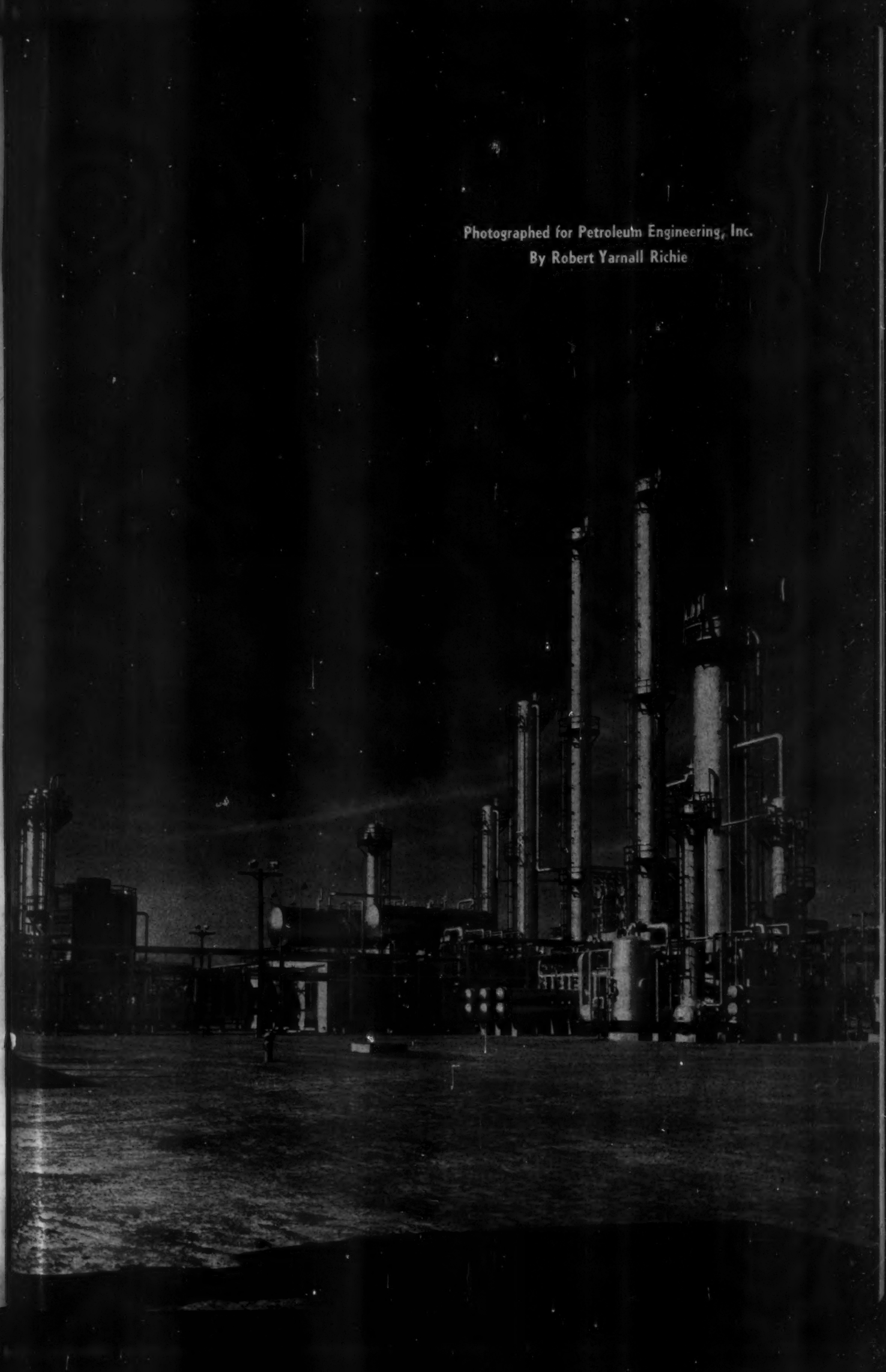
Cycle Stocks from Catalytic Cracking. C. L. BROWN, A. VOORHIES, JR., AND W. M. SMITH. *Ind. & Eng. Chem.* **38** (1946) pp. 136-40.

The purpose of the authors' paper is to present a discussion of an adaptation of the hydrogenation process that has not yet been commercially applied but which has potentialities for the future, particularly in conjunction with catalytic cracking. The procedure is directed primarily to the saturation of aromatics, especially the refractory condensed-ring molecules present in catalytically cracked cycle stocks. The hydrogenation of the aromatic components in refractory, catalytically cracked, cycle stocks to their corresponding naphthene derivatives results in improved catalytic-cracking feed stocks that are superior even to the original virgin gasoils. Higher conversions are obtained under similar cracking conditions; less carbon and more gasoline result for a given degree of cracking. Gasoline octane numbers are at least as good as those obtained with virgin feed stocks. Hydrogenation conditions used are generally the same as for the conventional high-pressure destructive hydrogenation of gasoils directly to gasoline except for the catalyst which, similarly, is sulfur resistant. Yields of hydrogenated cycle stock are 100 percent or more in all cases, with little change in boiling range and virtually complete sulfur removal. A combination of catalytic cracking with hydrogenation of all cycle stock and recracking to ultimate gasoline yield combined with fullest utilization of light hydrocarbons (C_3, C_4, C_5) by isomerization and alkylation is shown by calculation to result in an over-all volumetric yield of 90 percent of 100-octane gasoline. The use of lower pressures (750 as compared to 3000 psig) result in partial saturation of aromatics with rather complete desulfurization. The results of the work are presented in considerable detail.

Design and Performance of Cooling Towers. W. K. HUTCHISON AND E. SPIVEY. *Trans. Inst. Chem. Engrs.* **20** (1942) pp. 14-29.

The performances of cooling towers of standard design, including chimney-draught and forced-draught types, were correlated on a basis of the heat transfer in unit time and on unit cross-section of the tower, in relation to the inlet water temperature and to the degree of approach to the wet-bulb temperature. Application of the theoretical treatment of the problem showed that the performance of any of the cooling towers studied could be expressed with a close degree of accuracy in terms of a single mass transfer coefficient that can be used for the calculation of results lying outside the range of experimental verification, and as a basis for comparison with other designs. The conclusion was reached that the performance of towers would be improved by the substitution of smooth boards on edge for the triangular bars commonly used. A multiple-trough type of distributor is believed to be best from the standpoint

This cycling plant, recently completed, is one of many gas processing units designed and constructed by Petroleum Engineering, Inc., in the past 16 years of continuous service to the industry. Petroleum Engineering, Inc., Offices: Houston and Tulsa.



Photographed for Petroleum Engineering, Inc.
By Robert Yarnall Richie

of eliminating entrainment. Results are presented covering a study of an experimental cooling tower designed along the suggested lines and with provision for measurement of air and water. The results confirmed the validity of the method of analysis proposed and used. The efficiency of the fans normally used was studied, and it was concluded that a correctly designed propeller fan with blades of true aerofoil section would give a considerable saving in power. This was experimentally confirmed. Several full-scale cooling towers have been designed and built on the basis of the investigation reported, and the results secured with them show complete agreement with those obtained in the experimental unit. Approaches of 1°-4°F. to the wet-bulb temperature are shown to be practicable.

Apparatus for Flash-Distillation of Butadiene. A. P. Hobbs and M. R. Rector. *Ind. & Eng. Chem., Anal. Ed.* **18** (1946) pp. 140-41.

In the analysis of butadiene, the determination of C_5 hydrocarbons by a Dorell weathering tester gives high percentages if butadiene dimer is present. It has been customary to remove the dimer by flash distillation, but previous methods of accomplishing this have been defective in failing to give a complete removal of the dimer without loss of the C_5. An apparatus for the flash-distillation of butadiene is described. Its efficiency was determined with the aid of the Dorell weathering-test apparatus. Substantially complete removal of butadiene dimer is accomplished without appreciable loss of C_5 hydrocarbons.

Chromium Oxide as a Promoter in Catalysts for the Fischer-Tropsch Synthesis. J. C. Ghosh and S. L. Sastry. *Nature* **156** (1945) p. 506.

The economics of synthesis of hydrocarbons by the Fischer-Tropsch process can be improved (1) by using cheaper catalytic material, (2) by using water gas in place of enriched synthetic gas, and (3) by using medium pressures instead of atmospheric pressures. A cheap iron-copper catalyst prepared by Ghosh and Sen gave 86 gm. of hydrocarbons per cubic meter of gas. A catalyst containing chromium oxide that has a very high adsorption for hydrogen at 200°C. has been found to be remarkably steady, and yields 160 gm. of liquid hydrocarbons per cubic meter. The composition of the catalyst is given.

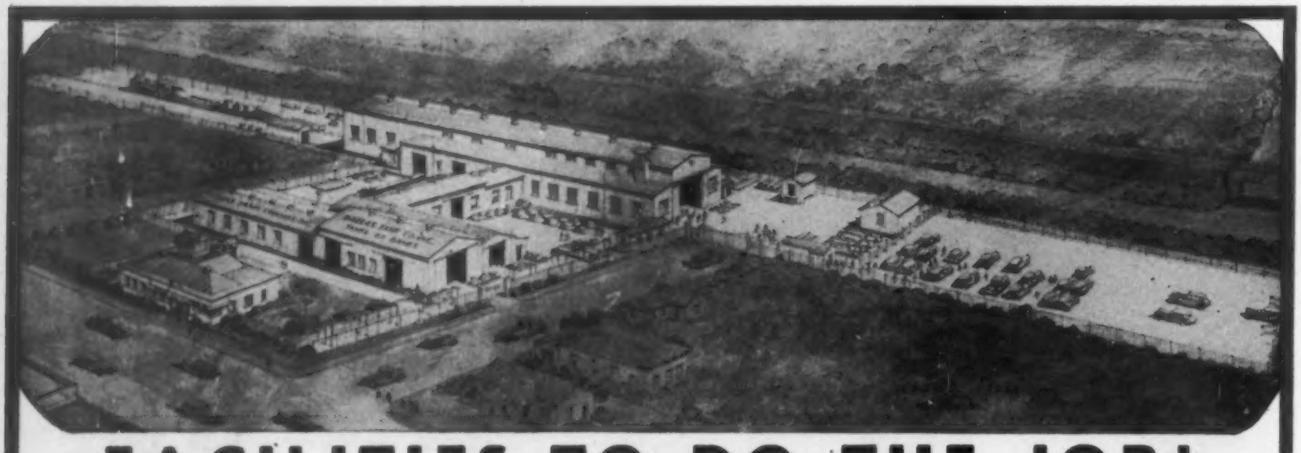
Products: Properties and Utilization

Analysis of Ternary Mixtures of Methylcyclohexane-Toluene-Aniline. C. S. Carlson, A. E. Schubert and M. R. Fenske. *Ind. & Eng. Chem. Anal. Ed.* **18** (1946) pp. 109-11.

A method of analyzing the ternary mixture methylcyclohexane-toluene-aniline has been developed. The refractive index of the ternary mixture and of the residual binary hydrocarbon after removing the aniline by acid extraction completely defines the ternary system. With the aid of an experimentally established curve, the ternary analysis can be found. The procedure is rapid and of good accuracy.

Correlation of Chemical Constitution and Oxidation Susceptibility of Lubricating Oil Components. S. F. Kapff, J. R. Bowman and A. Lowry. *Jour. Inst. Petr.* **31** (1945) pp. 453-74.

The paper presents the result of a study of the influence of chemical constitution on the susceptibility to oxidation of the several general types of components in petroleum lubricating oils. A fractionation of a Pennsylvania lubricating-oil stock was effected by distillation and extraction. The physical properties of the fractions and their chemical constitutions as calculated by Waterman's method are reported. Selected fractions were oxidized, and the extent of oxidation was measured by the acidity developed and by the increase of viscosity. The development of acidity can be roughly taken as a measure of the attack on the side chain. Increase in viscosity, even more roughly, as an indication of condensation. In summarizing the results of the oxidation work, the authors state that naphthenes are the most resistant to oxidation of all of the natural components in the stock, paraffins tend to form acids without much condensation to cause viscosity increase, and aromatics are subject to the formation of condensation products, presumably of high molecular weight, which increases the viscosity but do not increase the acidity greatly.



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1—Electronic Air Filter

American Air Filter Company, First and Central Avenue, Louisville 8, Kentucky, announces the "Electro-Cell," a unit-type electronic air filter with removable collector-plate assemblies, as one of the latest types now being manufactured.

The positive and negative collector plates are assembled on crossrods to form horizontal groups which are easy to handle and may be readily removed from the filter casing. This makes possible a number of innovations in construction which simplify installation, improve performance, and assure better maintenance.

Sliding into the filter casing in much the same manner as a desk drawer, plate assemblies can be removed for cleaning and recoiling at convenient water and sewer connections. By keeping a spare set of plates sufficient for one section for use as a replacement, the time the filter is out of service is reduced to a minimum, and the dirty collector plate assemblies can be cleaned at a time that is most convenient for maintenance personnel. An automatic washing device has been developed permitting collector-plate assemblies to be washed in place for installations where manual washing is not feasible.

Standard sections of the "Electro-Cell" are 2 and 3 feet in width with a capacity of 1000 cfm per unit and range from this minimum to as many sections as are needed for the particular installation. The construction of the filter is such that it eliminates the duplication of top and bottom sections of box-like units when assembled one upon another. This is accomplished by the manufacture of the filter in a variation of heights from a minimum of 27 inches to a maximum standard height of 15 feet by 9-inch increments.

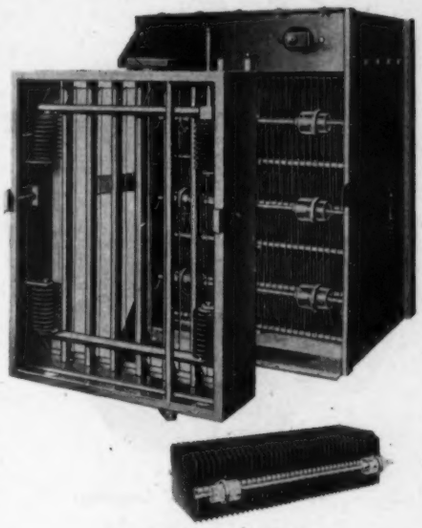
In the larger sizes of the "Electro-Cell" (6 feet or higher), the ionizers are mounted on a bar hinge which swings clear of duct work or adjacent sections giving full access to collector plates. Extending the full height of the section, electrical losses are reduced to a minimum due to fewer wire ends.

CHECK THE CARD AT PAGE 273

2—Mixer

Eastern Engineering Company announces a heavy-duty side-entering industrial mixer, Series SEG. Geared to operate at speeds up to 800 revolutions per minute, with the usual recommended speed of 400 revolutions per minute in tanks of all types of viscous materials which have a marked tendency to channel. By use of large slow-speed propeller a large mass is moved at a slow speed, giving time for the following material to flow into position to be moved at the next revolution of the propeller.

An exclusive feature of this mixer is its mechanical rotary seal which reduces



"Electro-Cell" Air Filter

seal wear, power loss and friction heat to a minimum. The lapped face of the stainless-steel sealing surface rotates against a stationary carbon sealing ring. The ring is held in position by a metal spring, and is sealed against the body of the mounting flange by a synthetic-rubber or plastic washer. Materials can be selected to meet particular conditions.

Models are available in sizes from ¼ to 30 horsepower.

CHECK THE CARD AT PAGE 273

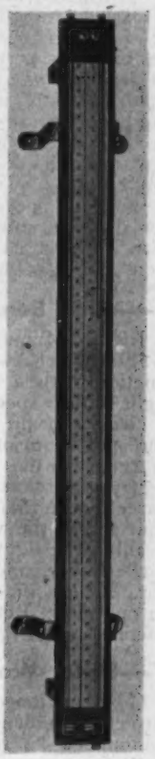
3—Heat Insulation

The Philip Carey Manufacturing Company, Lockland, Cincinnati 15, Ohio, has released a revised edition of its catalog: "Heat Insulation for Industry." It has been developed to facilitate the specification and purchase of heat insulation. In addition to complete information on over 40 company products, this catalog contains heat-loss tables, selection charts and data for determining insulation thickness, comparative efficiencies, mechanical, thermal and performance characteristics, and other information concerning magnesia, asbestos, sponge, diatomacious earth, calcined aggregate, mineral wool and corrugated asbestos. Insulating, bonding and refractory cements also are covered.

CHECK THE CARD AT PAGE 273

4—New Type Manometer

The Meriam Instrument Company, 10920 Madison Avenue, Cleveland 2, Ohio, has announced a new manometer development — the "Dual-Tube" Meriam Model M-100. It consists of two separate monometer tubes in the same case—each tube with individual well. It enables the operator to read high range pressures, vacuums, and differentials from the floor level.



The left tube has a scale increasing upward; the right tube a scale increasing downward. Both tubes are connected in parallel to the same pressure source. The instrument is available in ranges of 50 to 150 inches.

The instrument is described by the maker as ideal as a calibrating standard manometer for checking flow meters, pressure gauges and other secondary units operating on pressure or vacuum principle. It is direct reading, the operator can choose the one most convenient.

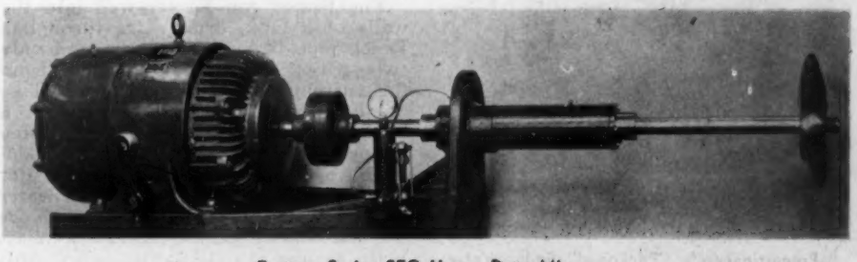
This dual-tube manometer is claimed to help avoid accidents because of its ease in reading from floor level, and to save time and effort in reading.

Catalog Sheet M-100WM gives complete details.

CHECK THE CARD AT PAGE 273

5—Oxygen Recorder

Bailey Meter Company, 1050 Ivanhoe Road, Cleveland 10, Ohio, has developed a new automatic continuous analyzer for indicating and recording the oxygen content of a gaseous mixture. This instrument has been successfully applied to petroleum and chemical processes, boiler furnaces and many types of metallurgical furnaces. It pro-



Eastern Series SEG Heavy Duty Mixer

vides a graphic analysis almost instantly, and is said to be responsive to changes of .05 percent oxygen. Sustained accuracy is said to be within .25 percent.

In operation a continuous gas sample is mixed with a vaporized liquid fuel and burned on a catalyst-filament which reaches a temperature proportional to the oxygen content. The filament resistance is a function of temperature and a simple resistance bridge is connected to a null-balance electronic recorder which may be calibrated in excess air, percent oxygen, or other desired terms.

A high-speed sampling system for handling dirty, high-temperature gases is furnished when required.

Oxygen recorders applied to all types of furnaces operating with oxidizing atmospheres permit closer regulation of fuel-air ratios, especially where multiple fuels are used, or where the firing rate changes rapidly. This results in not only greatly increased economy but also in decreased furnace maintenance.

Its high speed suits the instrument for traverse studies and other types of test work as well as continuous operation.

CHECK THE CARD AT PAGE 273

6—Wide Beam Flashlight

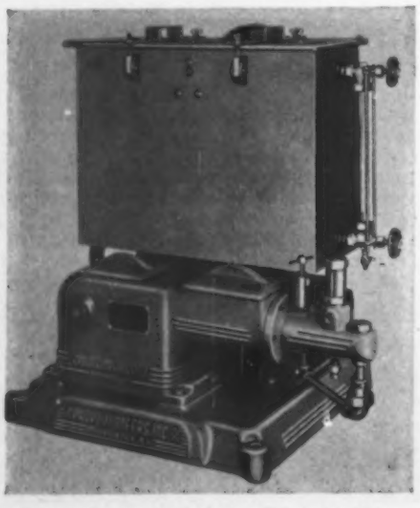
Justrite Manufacturing Company, 2061 N. Southport Avenue, Chicago, is in production with a three-cell plastic flashlight with a special lens which provides a circular beam three times as large as the spot beam of the usual flashlight. It is reported that at a distance of eight feet this new unit covers an area about three feet in diameter with a clear beam that lights the work area brightly and evenly. The light is 5¾ inches high, 2¾ inches wide, and has a 2½-inch reflector. Case is of durable plastic moulded in one piece. Reflector and lens ring are metal.

CHECK THE CARD AT PAGE 273

7—Boiler-Water Conditioner

%Proportioneers, Inc.%, 78 Codding Street, Providence 1, Rhode Island, has announced "a real packaged unit" for boiler-water treatment. The unit includes a %Proportioneers% "Adjust-O-Feeder" compactly mounted with a motor on the same base with a chemical tank and agitator. It automatically feeds all treating chemicals or compounds.

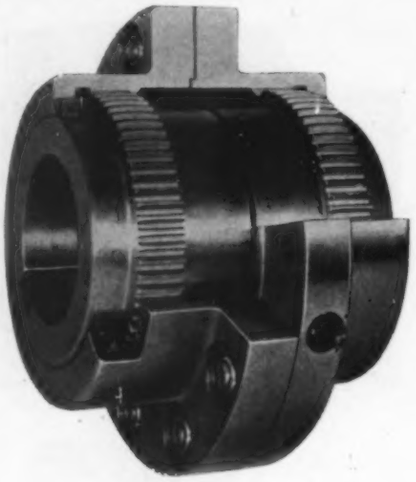
CHECK THE CARD AT PAGE 273



%Proportioneers% "Packaged" Boiler-Water Conditioner.

8—Gear Type Coupling

John Waldron Corporation, New Brunswick, New Jersey, announces that a new "Series A" coupling has been designed for a much larger maximum bore to permit use of smaller couplings than ordinarily would be required. The smaller coupling takes up less space, needs less shaft extension, looks better and costs less.



Waldron "Series A" Coupling

This Waldron coupling is all steel, made to close manufacturing tolerances, dust proof, oil tight, identical externally geared hubs that key to shafts, enclosed by one-piece male and female sleeves that function as a single unit. It compensates for misalignment without adding stress to shaft or bearing. Couplings are made in standard, heavy-duty, marine, mill-motor, floating-shaft, Jordan, shear-pin, oil-collector and cut-out types.

Catalog 57 gives complete details.

CHECK THE CARD AT PAGE 273

9—Electric Immersion Heater

American Instrument Company, 8010 Georgia Avenue, Silver Spring, Maryland, announces a new automatic electric safety immersion heater for liquids. This heater and its automatic control, in one unit, is for installation in water tanks, drums, processing kettles, stills, sterilizers, pipe lines, etc. It can be installed in any container where automatic and dependable heat is required for heating liquids.

Once installed and set for the desired working temperature, it will function accurately without further attention.

The built-in safety control will limit the temperature rise of the heater and thus protect it against overheating and burning out should the liquid level fall and expose the heating element to air.

The heater can be screwed into the walls of a tank, drum, etc., through a 1-inch pipe fitting or reducer, and only two wires need be connected from the current supply to the heater. Two or more heaters may be installed on one application and adjusted for step temperature control, or, where it is desirable to install more than one heater in the same vessel, the safety heater can be used to regulate one or more non-automatic heaters through a relay.

By turning an indicating screw, this heater can be set as desired from room temperature to 350° F., and will maintain the temperature of liquids within plus or minus 5° F.

The sheath of this heater can not become electrically energized, thus there is no danger of the material becoming electrically charged.

A pilot light indicates when the heater is functioning.

These heaters are available with copper sheaths for heating water, or with steel sheaths for heating light oils, in wattage ratings of 250, 500, 750, and 1000.

Complete details are given in manufacturer's Bulletin 2132-184.

CHECK THE CARD AT PAGE 273

10—Flux-Coated Bronze Welding Rod

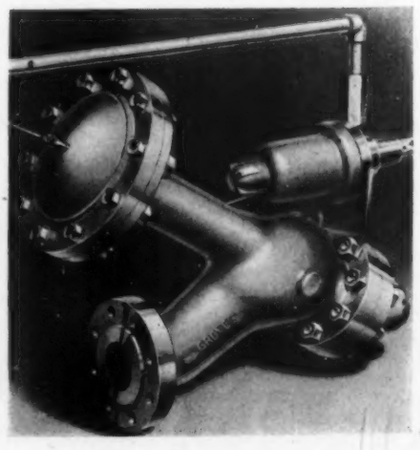
A new flux-coated bronze welding rod for application by the oxy-acetylene process has been developed by The Linde Air Products Company, Unit of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York. Known as "Oxweld" No. 25M Flux-Coated bronze rod, this new rod combines the properties of "Oxweld" No. 25M. bare bronze rod with correct fluxing. When the rod is made, it is pre-coated with flux in proper proportion to its size. This coating consists of "Brazo" flux plus a non-active binder that does not affect the weld. It adheres firmly to the rod, melting down into the molten puddle without burning off ahead of the rod. The rod can be heated and bent without destroying the coating. In addition, the coating is not affected by weather conditions.

"Oxweld" No. 25M. Flux-Coated bronze rod speeds up the welding operation and makes it easier to produce welds of uniformly high quality. The operator can give his entire attention to depositing the rod metal and controlling the molten puddle without the usual delays of dipping the end of the hot rod into the flux container. The flux melts into the weld continuously and in the right quantities, leaving no wasteful residue on the face of the weld. Thorough tinning, essential to good bronze-welding, continues without interruption.

CHECK THE CARD AT PAGE 273

11—Valve

Grove Regulator Company, 6541 Green Street, Oakland 8, California, has announced a back-pressure, relief and stack valve, designed for maximum flow and freedom from freezing, and said to represent a marked advancement in valve



Grove Valve

design, construction and operating performance. Its free-flow characteristic is attributed to an unusually straight flow, resulting from a 30-degree S-pattern valve body design, which eliminates turbulence.

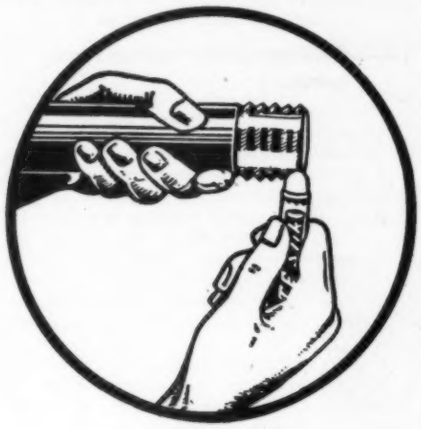
Actual capacity of the valve is said to be equivalent to conventional double seated globe valves, yet single seated valve and pilot construction is employed.

Full description is contained in bulletin 500.

CHECK THE CARD AT PAGE 273

12—Pipe-Joint Compound

Lake Chemical Company, 607 North Western Avenue, Chicago 12, has announced "Pipetite-Stik," a pipe-joint compound in stick form. Application is by rubbing three or four strokes of stick across the threads. It spreads and fills threads when turned.



"Pipetite-Stik"

The compound withstands gasoline, oil, butane, propane, gas, air, water, steam, brine, etc. Joints disconnect easily after months of service. It lubricates and seals pipe-thread joints, bolts, etc., and cannot flow into and clog even the smallest pipe. Withstands vibration, temperature change, deflection and pressure. Joints can be remade without cleaning. It contains no lead and no injurious ingredients.

CHECK THE CARD AT PAGE 273

13—Stainless-Steel Electrodes

The Lincoln Electric Company, Cleveland, Ohio, has announced two electrodes for shielded-arc welding of stainless steels. Known as "Stainweld A 7" and "Stainweld A 7-Cb," they are made for welding steels of the 18 percent chromium and 8 percent nickel type in all positions.

"Stainweld A 7," which was discontinued during the war, has been improved and is now being manufactured. It is recommended for use with stainless steels designated by American Iron and Steel Institute as numbers 304 and 308. It produces a smooth and steady arc with easy slag removal and is suited for operation on direct or higher-voltage alternating current welding units. It is available in 1/16-, 5/64-, and 3/32-inch sizes; 18-inch lengths, center grip and 1/8-, 5/32- and 3/16-inch sizes; 14-inch lengths, end grip.

"Stainweld A 7-Cb" is columbium stabilized and has operating characteristics similar to "Stainweld A 7". This electrode is recommended for use with stabilized 18-8 stainless steels designated

IMPORTANT

FOR THE MAN IN CHARGE OF *PRESSURE GAGES*

This is the first technical catalog written on pressure gages. It explains the theory of operation and gives all the technical details of modern gage construction. It tells how the Helicoid movement works—an exclusive feature of Helicoid Pressure Gages. If you use any quantity of pressure gages in your operations, the man in charge of your gages should have a copy of the new Helicoid Gage catalog.

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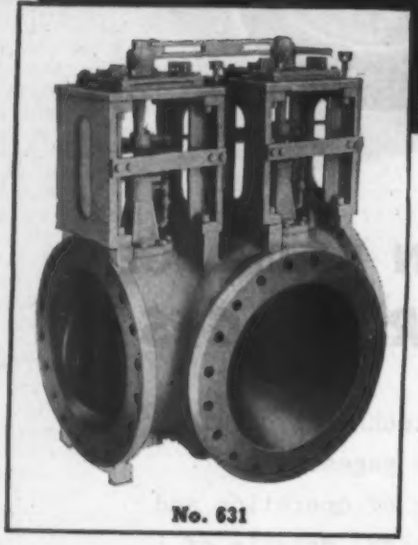
AMERICAN CHAIN & CABLE
Bridgeport 2, Connecticut

TRADE MARK

No. 630

15 to 900 psi
Control and shut-off of volume and pressure for air, gas, steam, liquids and semi-solids

TORQUE IS EQUALIZED
in *Quick Operating*
Three-Way Valves



No. 631

All R-S Butterfly Valves are precision engineered, metallurgically and mechanically, and this is the chief reason why the Three-Way Valves have met widespread approval and acceptance.

Designed for mixing and quick interchange service, these valves are adapted to pressures from 15 to 900 psi and for elevated or sub-zero temperatures. In manual operation, four to six revolutions of the hand wheel fully open or close the valve vane. Adjustable linkage is usually provided so that the mixture can be changed at will.

With a pressure drop across the valve, the vane tends to close itself. The torque on the closed right-hand vane (see illustrations) is opposite to that on the open left-hand vane so that the torque is equalized and no excessive load is placed on the motor in power-operated installations.

Available in sizes from four to sixty inches. Write for details and Catalog No. 14-B.

VALVE DIVISION
R-S PRODUCTS CORPORATION
120 Berkley Street • Philadelphia 44, Pa.

R-S Streamlined BUTTERFLY VALVES

by American Iron and Steel Institute numbers 321 and 347. It is furnished in 3/32-inch size; 18-inch length, center grip and 1/8-, 5/32- and 3/16-inch sizes; 14-inch lengths, end grip.

Both "Stainweld A 7" and "Stainweld A 7-Cb" shielded arc electrodes are also recommended for weld-surfacing where an austenitic (work-hardening) surface of medium hardness and good corrosion resistance is required. It provides excellent resistance to impact and abrasion. Hardness of single layer, as deposited on mild steel, 35 Rockwell C; work hardened, 48 Rockwell C; of multiple layer, as deposited, 85 Rockwell B; work hardened, 42 Rockwell C.

Shape of weld bead with either electrode generally is convex.

Properties of all-weld metal specimen (average for various sizes of electrodes): Tensile strength—85,000 to 95,000 pounds per square inch. Elongation is 2 inches—35 percent to 50 percent.

CHECK THE CARD AT PAGE 273

14—Bellows-Differential Flowmeter

The Bristol Company, Waterbury 91, Connecticut, announces the addition of a bellows-differential flowmeter to its line of mercury manometer flowmeters.

The new instrument, known as the Bellows-Differential Flowmeter, will be made as a mechanical flowmeter, as an electric flowmeter, and as a pneumatic-transmission flowmeter in a complete line of recording, indicating, integrating, and automatic controlling models.

The meter body, operating on a new principle, requires no mercury in its operation. A unique method of transmitting bellows motion to the pen arm is employed, which completely isolates the meter-body shaft from the measured fluid.

The new instrument is described in the company's bulletin F1603.

CHECK THE CARD AT PAGE 273

15—Four-Way Transfer Valve

R-S Products Corporation, Wayne Junction, Philadelphia 44, has announced availability of a new 125-pound single-vane quick-operating control valve for use to transfer oil, chemicals, sewage and other materials from one line to another. It can be manually or automatically operated. Available for a wide range in pressure together with sub-zero and elevated temperatures. Equipped with adjustable stop screws and indicator to determine vane position. Can be fabricated from all types of metals in sizes from 4 to 72 inches.

This valve is constructed of R-S "A" metal, a tough, dense metal of uniform grain and high endurance limit. These properties make it suitable for applications which give rise to hard wear and severe stresses; it resists wire-drawing and the wearing action of abrasive materials, according to the manufacturer.

CHECK THE CARD AT PAGE 273

16—Portable Brazer

Westinghouse Electric Corporation, Box 868, Pittsburgh 30, has announced a new portable 5 kva brazer for making lap joints in copper strap, attaching terminals to cable, brazing coil ends and general copper smithing work. The unit weighs only 30 pounds.

The new brazer, which requires connection to a 220-volt source, consists of a transformer, voltage selectors, con-

Natural Gasoline Plant and Refinery Equipment

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Tulsa Boiler & Machinery Co.

extends greetings to the membership and executive personnel of the Natural Gasoline Association, the Industry it has been our privilege to serve for so many years.

Tulsa Boiler & Machinery Co.

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Fig. 2125 Bronze Gate

you know you're buying BETTER EQUIPMENT

● The installation of Lunkenheimer Valves, Lubricators, or Air Devices on power equipment is an indication that the equipment itself is of *superior construction and efficiency.*

It's the quality-minded manufacturer who selects Lunkenheimer products for his equipment. He knows the Lunkenheimer reputation for correct engineering, advanced design, superior workmanship . . . he knows his equipment will give better performance with less trouble, when fitted with Lunkenheimer Valves or other devices.

Fig. 16 "Renewo" Globe

He knows, in short, that his own product is thus given added salability, and in use will give the purchaser maximum results at minimum cost.

Whenever and wherever you purchase power equipment units, you'll be wise to look for the Lunkenheimer name on valves and lubricators —*a positive guide to value.*

THE LUNKENHEIMER COMPANY, Cincinnati 14, Ohio, U.S.A. (Offices: New York 13, Chicago 6, Boston 10, Philadelphia 7. Export Department: 318-322 Hudson Street, New York 13, N. Y.)

Fig. 1430 Iron Body Gate

● *Perhaps YOU Have A Product That Can Be Given This Added Sales Advantage. If your products require the use of valves, lubricators, air devices, or boiler mountings, the name Lunkenheimer on such equipment will provide extra sales appeal. For further information see your nearest LUNKENHEIMER DISTRIBUTOR.*

Fig. 1834 "Alver" Constant Level Oil Control

Fig. 1571 Air Cock 150 Lb. Pressure

LUNKENHEIMER VALVES

BRONZE, IRON, STEEL, AND CORROSION RESISTANT ALLOY VALVES
AIR DEVICES, LUBRICATORS, AIRCRAFT FITTINGS

trols, and carbon-tipped tongs. Alternating current from an adjustable voltage transformer passes through the tongs and parts to be brazed, raising the temperature to a point at which the brazing alloy melts. The brazing alloy may be applied in a rod or ribbon form. Three outlets are provided on the control panel for 8, 6 or 4 volts. Voltages are adjusted by inserting bayonet plugs attached to the brazing leads into plainly marked receptacles. A foot switch with pilot cable serves as the primary control switch.

For use with air-cooled tongs, the new brazer is supplied with a handle for carrying. The 30-pound unit is cooled by natural air circulation. Air enters bottom of the case and is expelled through louvered openings in the top.

CHECK THE CARD AT PAGE 273

17—Testing Instrument

C. J. Tagliabue Division, Portable Products Corporation, 560 Park Avenue, Brooklyn 5, New York, has issued Catalog 699-G, on instruments for testing petroleum products. The book lists the company's complete line of ASTM and API hydrometers and thermometers, together with many similar instruments for miscellaneous testing and general laboratory use. Illustrations are plentiful and complete descriptions of all insrtuments are given. The 44-page booklet also contains conversion tables for temperature and specific gravity and a guide to principal tests of petroleum products.

CHECK THE CARD AT PAGE 273

18—X-Ray Equipment

North American Philips Company, 100 East 42nd Street, New York 17, is distributing a new 12-page booklet describing "Norelco Industrial X-Ray Equipment." It gives description and specifications of a number of units and includes a chart which shows the unit best suited for a given task.

CHECK THE CARD AT PAGE 273

19—Temperature Control in Instruments

H-B Instrument Company, 2519 North Broad Street, Philadelphia 32, has issued a new 16-page catalog on its line of temperature control instruments, for between —30 and 500° F.

CHECK THE CARD AT PAGE 273

20—Safety Appliances

Mine Safety Appliances Company, Pittsburgh 8, Pennsylvania, has issued a new complete catalog, 6-B, describing and illustrating its safety equipment, including many new items. Containing 178 pages, this catalog is available in 8½ x 11-inch or 5 x 6½-inch sizes, the smaller volume containing the same material as the larger except in miniature size.

CHECK THE CARD AT PAGE 273

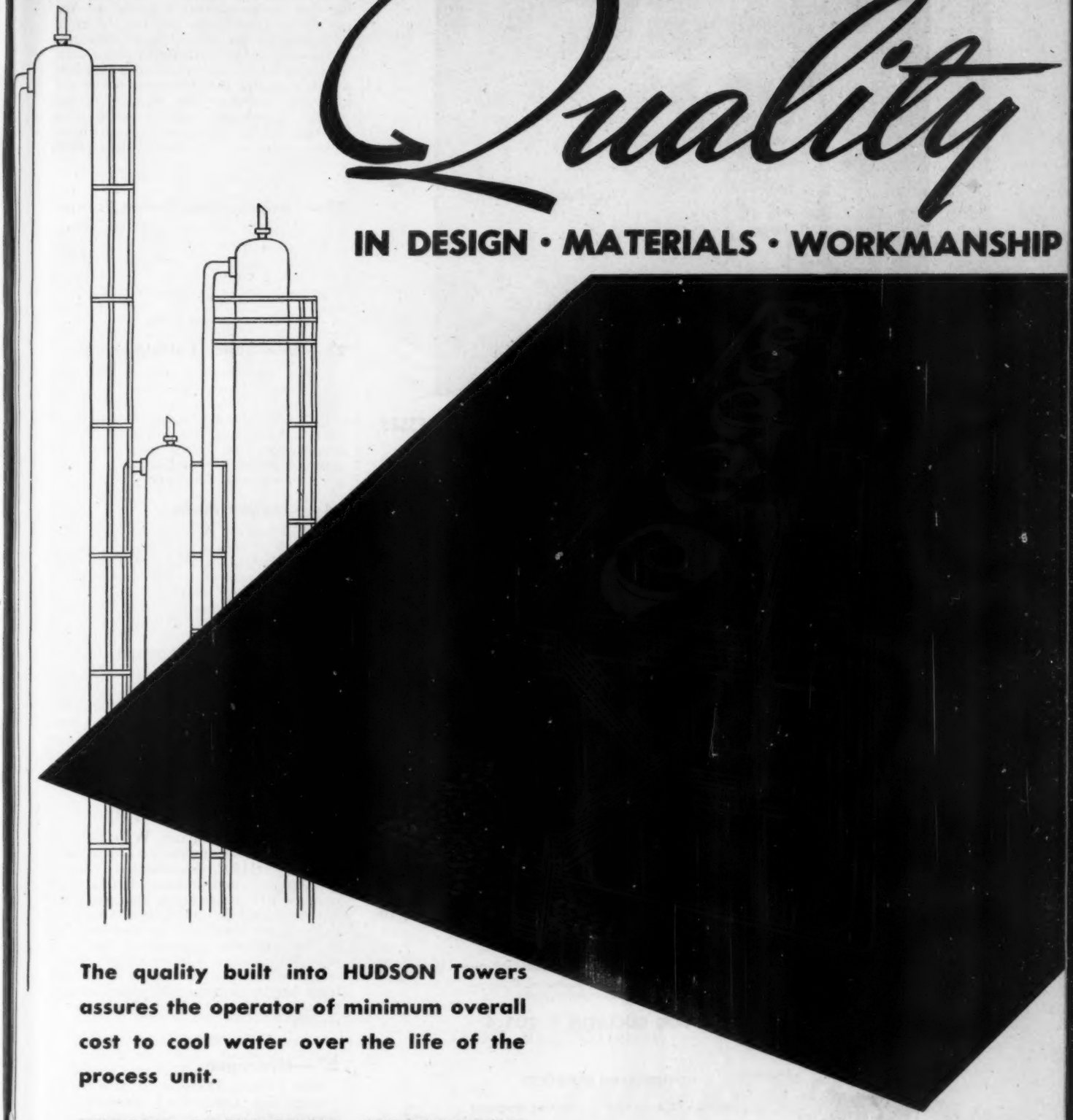
21—Fuel-Loss Calculator

Hays Corporation, Michigan City, Indiana, is offering a slide-rule type of calculator of particular interest to boiler-room operators.

The calculator is used after the percent of CO_2 in the flue gas, the temperature of the flue gas and the room temperature have been determined. The calculator is based on several fuels of

Quality

IN DESIGN • MATERIALS • WORKMANSHIP



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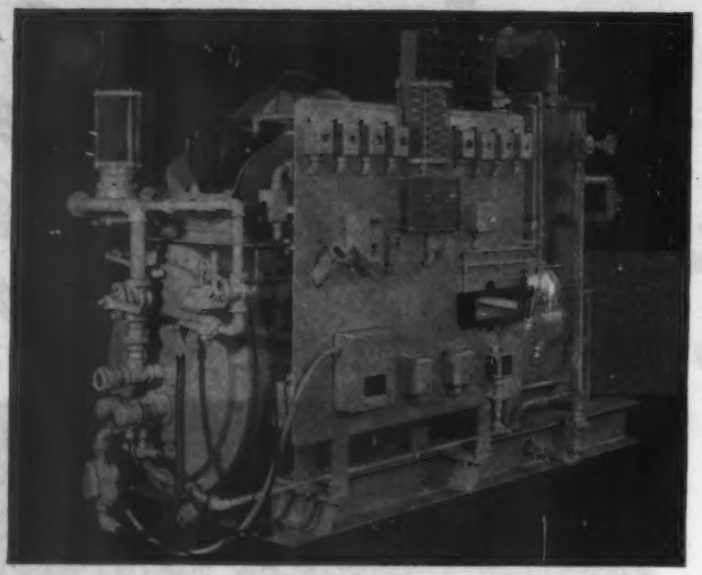

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Available in standard models in capacities ranging from 1,000 to 100,000 CFH —**larger sizes and special models built to order. All** models feature:

(1) Flexibility—gas production automatically responds to demand at any rate up to 100% of capacity—thus frequently eliminating need for gas holders to handle peak loads.

(2) Economy—fuel gas consumption also varies directly with demand—no wasteful venting.

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different analyses and a wide range of flue-gas temperatures. Figures on the calculator reveal the percent of total heat loss in the flue gas. Instructions accompanying the calculator show how heat loss can be converted into fuel loss which is really the information the engineer is seeking. The figures on the various scales are original calculations by the Hays engineering department.

The calculator is being distributed without cost.

CHECK THE CARD AT PAGE 273

22—Reciprocating Steam Pumps

Worthington Pump and Machinery Corporation, Harrison, New Jersey, has available reprints of an article on reciprocating steam pumps, by Darwin F. Schaub of the company's foreign division.

CHECK THE CARD AT PAGE 273

23—Emergency Cutting Outfits

Victor Equipment Company, 844 Folsom Street, San Francisco 7, is distributing a bulletin descriptive of an emergency flame cutting outfit developed for the Navy and now available for fire department and police use. Industrial safety application is indicated.

CHECK THE CARD AT PAGE 273

24—Oxygen Mask

Mine Safety Appliances Company, Braddock, Thomas and Meade streets, Pittsburgh 8, has available Bulletin BM-7, which describes a new demand-type oxygen mask for respiratory protection in unbreathable atmospheres.

CHECK THE CARD AT PAGE 273

25—Corrosion Protection

Haynes Stellite Company, Kokomo, Indiana, is distributing a new folder, "Hastelloy Facing for Corrosion Resistance." It describes two ways that have been developed for applying corrosion-resistant alloy to surfaces of equipment exposed to corrosive agents.

CHECK THE CARD AT PAGE 273

26—pH Equipment

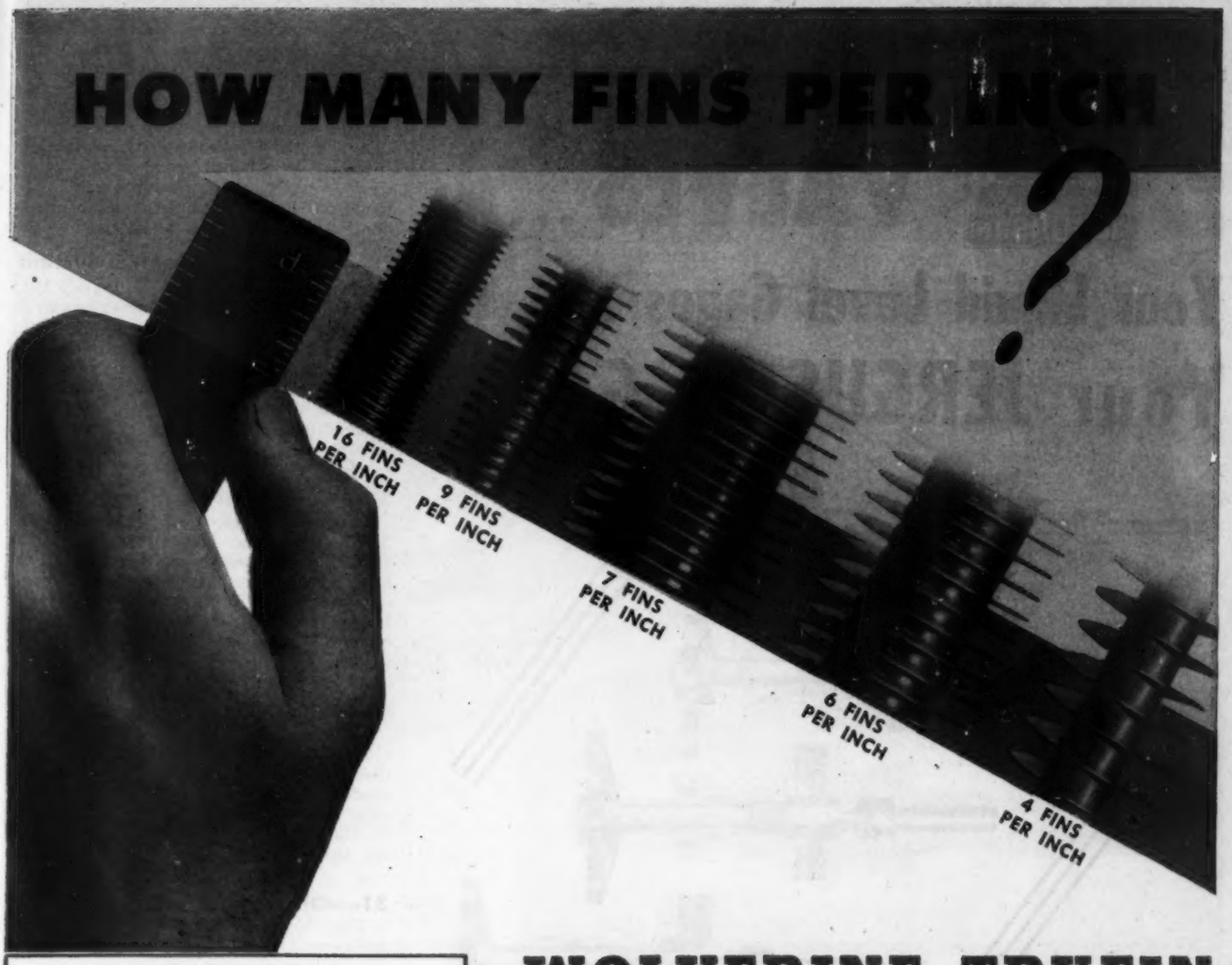
The Bristol Company, Waterbury 91, Connecticut, has announced a new bulletin, No. pH1302, describing its line of pH control instruments. Bristol continuous pH controllers and recorders are described in detail, including electrode assemblies and accessories. The bulletin includes engineering and technical information relative to pH theory and measurement. A variety of installations are described; with chart records, photographs, and flow diagrams included.

CHECK THE CARD AT PAGE 273

27—Hydrogen

Gas Process Division of The Girdler Corporation, Louisville 1, Kentucky, has issued a 32-page booklet which with text, pictures, flow diagrams and tables reviews the commercially useful methods of producing hydrogen. Included is a description of the new Girdler Hygirtol plant for production of high-purity hydrogen by reacting hydrocarbons with steam.

The booklet's comprehensive coverage is indicated by the following table of contents: Hydrogen, Commercial Methods of Production, Water Gas Process, Steam-iron Process, Methanol-steam Process, Electrolytic Process, Hydro-



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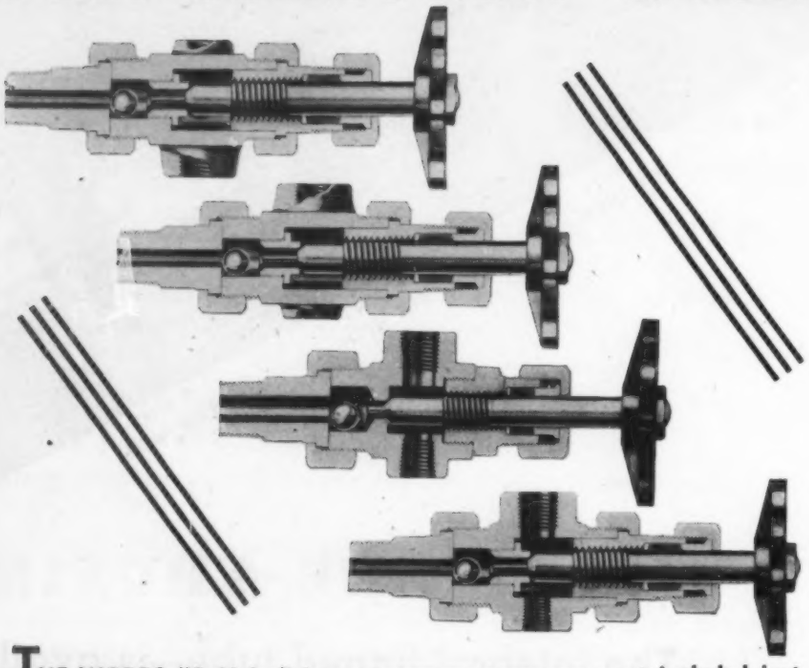

THE WORDS "& Valve" in our company name were not included just to make the name longer and more imposing. They cover an important division of our business . . . the design and manufacture of valves for gages for all liquid level indicating requirements.

Ever since we began to make gages years ago, we realized that the valves were as important as the gages themselves. We have put just as much engineering thought and manufacturing skill into our valves as into our gages.

Jerguson Valves are the ones to buy . . . for any liquid level gage installation. Always order them when ordering your Jerguson Gages. You can obtain any type valve desired: plain, automatic-closing, quick-closing, jacketed, offset.

We make gages and valves of any metal required to meet specific corrosive conditions. Valves are furnished with any type and size of connections required.

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carbon-steam Process, Carbon Dioxide Removal by the Girbotol Process, Methanation, Carbon Monoxide Removal by Cuprous Salt Solutions, Carbon Dioxide Removal by Soda Solutions, Carbon Dioxide Removal by Water Scrubbing, Dehydration, Deoxidation, Liquefaction, Special Gas Mixtures, Hydrogen Catalysts, Analysis of Hydrogen, Properties of Hydrogen and useful information.

CHECK THE CARD AT PAGE 273

28—Feed-Water Control System

Northern Equipment Company, 1945 Grove Drive, Erie 6, Pennsylvania, is distributing Bulletin 447—Feed-Water Control System for the World's Largest Forced-Circulation Boiler. It is an illustrated description of an installation in an Eastern power plant, and gives engineering details and performance records.

CHECK THE CARD AT PAGE 273

29—Condensers and Coolers

The Griscom-Russell Company, 285 Madison Avenue, New York, is distributing Bulletin 1230, featuring the Fin-Fan Exchanger for process water cooling developed in association with The Fluor Corporation, and giving details on the Griscom-Russell K-Fin Air-Cooled Section.

CHECK THE CARD AT PAGE 273

30—Slurry Handling

Worthington Pump and Machinery Corporation, Harrison, New Jersey, is distributing Bulletin W-350-B8, which discusses the problems of handling slurries. Included are typical uses and performance records of its line of pumps for this service.

CHECK THE CARD AT PAGE 273

31—Oil-Burning Equipment

The Volcanic Specialties Company, Alliance, Ohio, is distributing a bulletin on oil-burning equipmennt involving a system for "grinding up" sludges for use as fuel.

CHECK THE CARD AT PAGE 273

32—Homogenizers

Marco Company, Third and Church Streets, Wilmington 50, Delaware, has issued an attractive 20-page brochure on its line of homogenizers, with a section on transferring, metering and proportioning pumps.

CHECK THE CARD AT PAGE 273

33—Variable Flow Pumps

Worthington Pump and Machinery Corporation, Harrison, New Jersey, has issued Bulletin W-414-B50, on Worthington Automatic "Variflo" Triplex Power Pumps. It gives construction details and performance data on a unit operating at constant speed and delivering by automatic control the varying requirements as in boiler feed, process charging and similar operations.

CHECK THE CARD AT PAGE 273

34—Aluminumized Steel

The American Rolling Mill Company, Middletown, Ohio, has issued a 24-page booklet, "Armco Aluminumized Steel," that describes a new special-purpose sheet steel for resistance to heat and corrosion.

Aluminum-coated on both sides, aluminumized steel is described as resisting destructive heat scaling up to 1500°F. It maintains a bright shiny appearance after prolonged heating up to 900°F., has good atmospheric corrosion resistance, and good radiant heat re-

FOUR STRONG NON-CORRODIBLE

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BRAND
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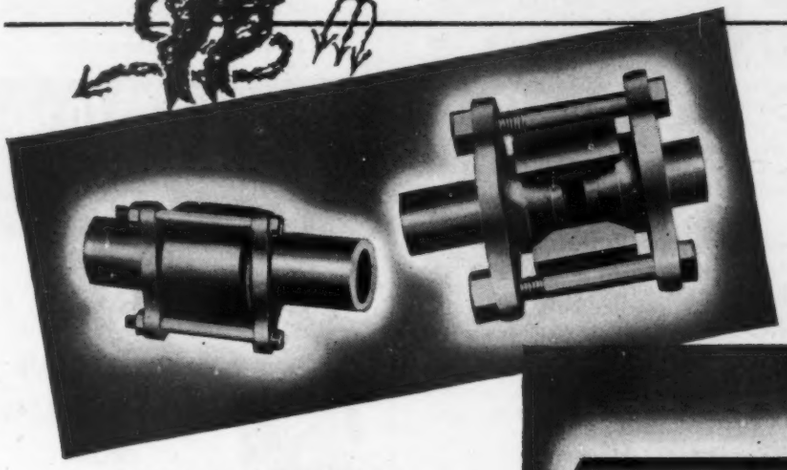
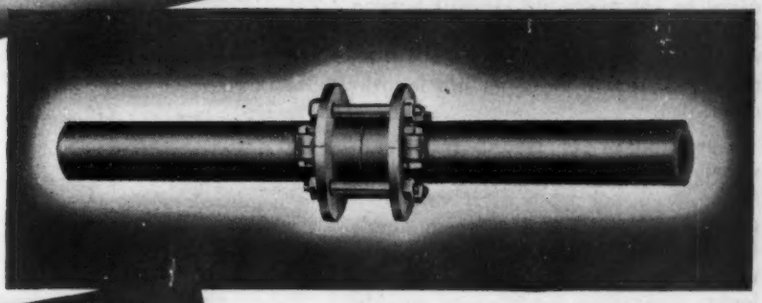


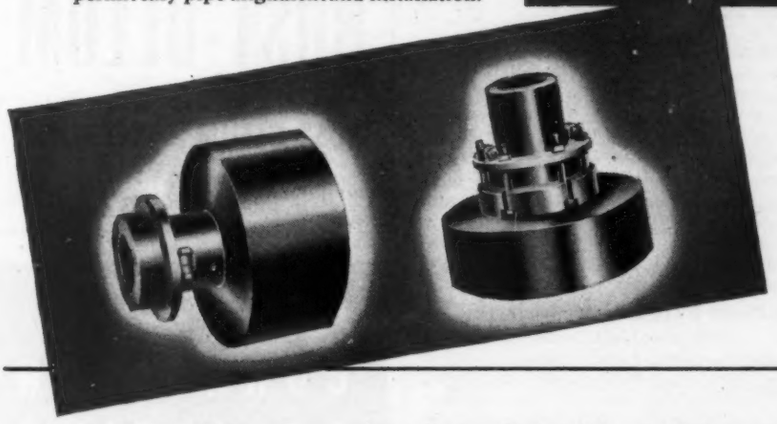
Type FC Flexible Coupling

Permits movement in any direction to protect "Karbate" piping from effects of vibration, misalignment, and differential expansion. Easily installed or dismantled on the job. Simplifies final pipe-length adjustment between pieces of equipment. Used with "Karbate" preassembled standard nipples and fittings, pipe may be cut to length and rapidly installed in the field.



Type V Flanged Connection

Thick, small-diameter collars provide sturdy construction. These can be used with companion flanges of almost any design or material. The separate cast-iron split flanges permit easy pipe alignment and installation.



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Type SC Slotted Coupler

Recommended for connections on "Karbate" tanks, towers, heat exchangers, and similar equipment. Generally installed at our factory—not particularly suitable for field installation. The Slotted Coupler is of more compact construction than the Type V Nozzle, but the choice of connection depends upon requirements of each job.

STRENGTH and ease of installation distinguish four improved "Karbate" chemically resistant equipment connections that are doing a first-rate job in many kinds of service.

Like the many "Karbate" specialty products used for **storage, conveying, handling,** and **processing** of corrosive liquids and gases, these connections are not only strong, but have high resistance to mechanical and thermal shock and to the action of most acids (notably hydrofluoric), alkalies, and other corrosive chemicals.

The designs of these connections are the result of years of experience of National Carbon Company, Inc., in furnishing "Karbate" impervious carbon or graphite equipment to the chemical, process, and other industries.

• • •

For additional information about "Karbate" equipment connections, write to our nearest Division Office for Catalog Section M-8805.

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Unit of Union Carbide and Carbon Corporation
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Tamp the putty firmly in place and allow to set overnight. It will harden like metal, expanding as it sets, insuring lasting tightness. Vibration will be greatly lessened, machine life lengthened.

Get Smooth-On No. 1 from your supply house in 1-, 5-, 25- or 100-lb. sizes—or direct from us if your supplier hasn't it. It will come in handy for countless emergency and routine repairs—for sealing cracks, stopping leaks, tightening loose parts quickly, economically. Easy to use—no heat or special equipment required.

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flectivity. In addition, this new sheet possesses the strength of steel at moderately elevated temperatures and has a lower coefficient of expansion than some widely used non-ferrous metals.

The booklet is fully illustrated with charts, photographs and tables, and contains sections on heat reflectivity, mechanical properties, forming properties, painting and finishing, electrical conductivity, welding, brazing, and soldering.

CHECK THE CARD AT PAGE 273

35—Midget Pumps—Stirrers

Eastern Engineering Company, New Haven, Connecticut, has issued a new catalog covering its line of midget pumps and laboratory stirrers. This is the first new literature on small pumps printed by this company since before the war. It contains descriptions and illustrations of many new models of small pumps both for regular industrial use and special types recently developed. In addition it includes the company's line of laboratory stirrers.

CHECK THE CARD AT PAGE 273

36—Safety and Relief Valves

Farris Engineering Company, 400 Commercial Avenue, Palisades Park, New Jersey, is distributing a new catalog, No. 45, featuring new designs and improvements of old designs of its line of safety and relief valves. A pictorial index shows line drawings of basic types as an aid in selecting the proper unit for a specific use.

CHECK THE CARD AT PAGE 273

37—Instruments

The Foxboro Company, Foxboro, Massachusetts, has issued its Catalog 370 on industrial instrumentation. Data includes indicating, recording and controlling instruments for process variables.

CHECK THE CARD AT PAGE 273

38—Relief Valve

Cochrane Corporation, 17th Street and Allegheny Avenue, Philadelphia 32, is distributing its Publication 4150 on the Cochran Multiport Relief Valve. Well illustrated, this booklet cites numerous applications in relief of steam, air, gas, gasoline and oil vapors, water, etc., and adaptability to other services. A section gives sizing data on relief valves, including capacity and pressure rise tables.

CHECK THE CARD AT PAGE 273

39—Heat Exchanger

The Griscom-Russell Company, 285 Madison Avenue, New York 17, has a new bulletin, No. 1614, which describes the "Twin G-Fin Section" for cooling, heating, condensing and heat-exchange services. The bulletin tabulates 21 features and corresponding advantages of this finned-tube unit, and describes in detail the design and construction. Many installation views are shown, together with field reports of service.

CHECK THE CARD AT PAGE 273

40—Pumps

Marco Company, Wilmington 50, Delaware, is distributing its Catalog No. 50, which describes its "Flow-Master" pumps for handling light and heavy viscous materials. It includes engineering data and prices.

CHECK THE CARD AT PAGE 273

41—Heat Exchangers and Condensers

The Pfaudler Company, Rochester 4, New York, has issued its Manual No.

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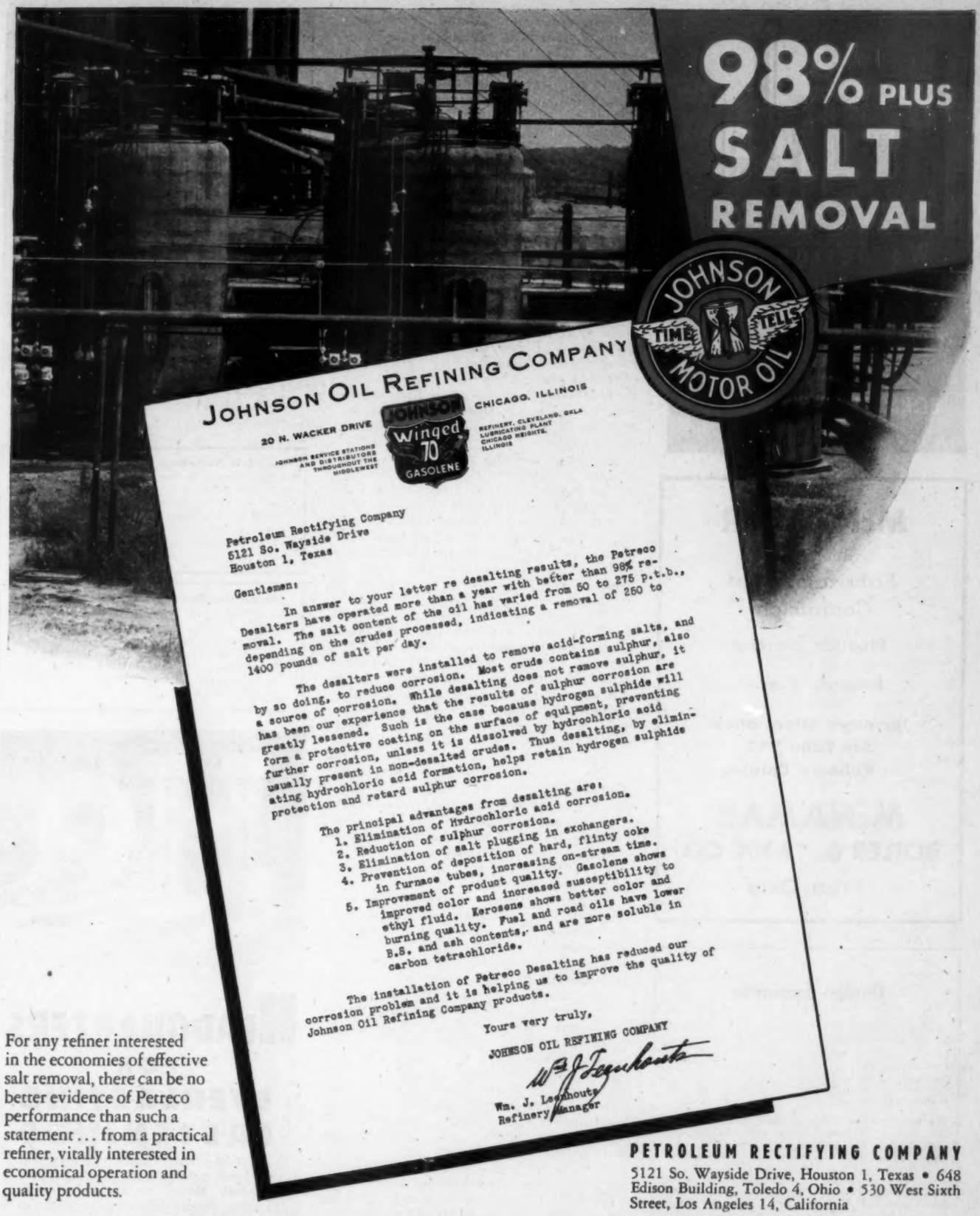

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The desalters were installed to remove acid-forming salts, and by so doing, to reduce corrosion. Most crude contains sulphur, also a source of corrosion. While desalting does not remove sulphur, it has been our experience that the results of sulphur corrosion are greatly lessened. Such is the case because hydrogen sulphide will form a protective coating on the surface of equipment, preventing further corrosion, unless it is dissolved by hydrochloric acid usually present in non-desalted crudes. Thus desalting, by eliminating hydrochloric acid formation, helps retain hydrogen sulphide protection and retard sulphur corrosion.

The principal advantages from desalting are;

1. Elimination of Hydrochloric acid corrosion.
2. Reduction of sulphur corrosion.
3. Elimination of salt plugging in exchangers.
4. Prevention of deposition of hard, flinty coke in furnace tubes, increasing on-stream time.
5. Improvement of product quality. Gasolene shows improved color and increased susceptibility to ethyl fluid. Kerosene shows better color and burning quality. Fuel and road oils have lower B.S. and ash contents, and are more soluble in carbon tetrachloride.

The installation of Petreco Desalting has reduced our corrosion problem and it is helping us to improve the quality of Johnson Oil Refining Company products.

Yours very truly,

JOHNSON OIL REFINING COMPANY

Wm. J. Leenhouts

Wm. J. Leenhouts
Refinery Manager

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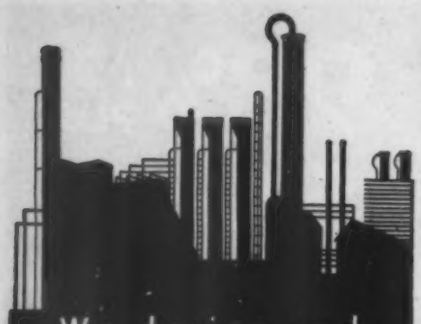

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837 covering new Pfaudler standard stainless-steel heat exchangers and condensers. This manual is of particular value in that it covers the subject completely with factual data; including such an application chart, physical properties chart, and several temperature, thermal and calculation charts and tables. Photographs and line drawings illustrate both construction details and service installations of the equipment.

CHECK THE CARD AT PAGE 273

Fluid Measurement Engineer Handbook

A complete yet concise treatment of fluid measurement, including related factors, equipment, equations and computations in terms of steam, water, oil and gas flow, is offered in a new volume, The Flow Meter Engineering Handbook, compiled and edited by Louis Gess and R. D. Irwin, flow meter engineering department, Brown Instrument Company division of Minneapolis-Honeywell Regulator Company.

The new volume, replete with information for students as well as engineers, is the second edition published by the company. In it the authors preface their efforts with the following comment:

"... The second edition has been written to expand the original information and to include suggestions made by users of the first edition to improve its usefulness.

"Wherever possible the authors have used the same symbols for fluid measurement as the American Society of Mechanical Engineers' research publication, 'Fluid Meters, Their Theory and Application' . . . Derivations of formulae include those of a universal formula for fluid measurement with a thin orifice, practical working equations, and the use of Reynolds' Number Recommendations of the Joint American Gas Association-American Society of Mechanical Engineers' Committee on fluid measurement for orifice installations are included. Separate chapters have been devoted to compressibility of gases, orifice calculations for various fluids, and the application of correction factors."

The first chapter discusses principles of orifice meter measurement followed by succeeding chapters on the orifice plate and differential connections, design details of Brown flow meters, flow approximation tables, derivations of working formula, working equations, compressibility of gases, relationship between coefficient of discharge, viscosity of fluids and orifice calculations for steam, water, oil and gas flow.

The final chapters are given over to a summary of equations and nomenclature, changes for corrections in operating conditions, and volume computations. Thirty-eight figures and 55 tables are included in the book's 151 pages.

The Flow Meter Engineering Handbook is being published by Brown Instrument Company, 4498 Wayne Avenue, Philadelphia 44. It is priced at $2.50 a copy.

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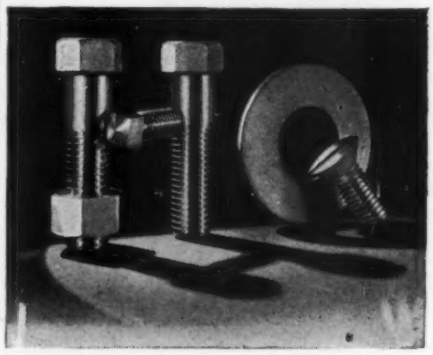

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